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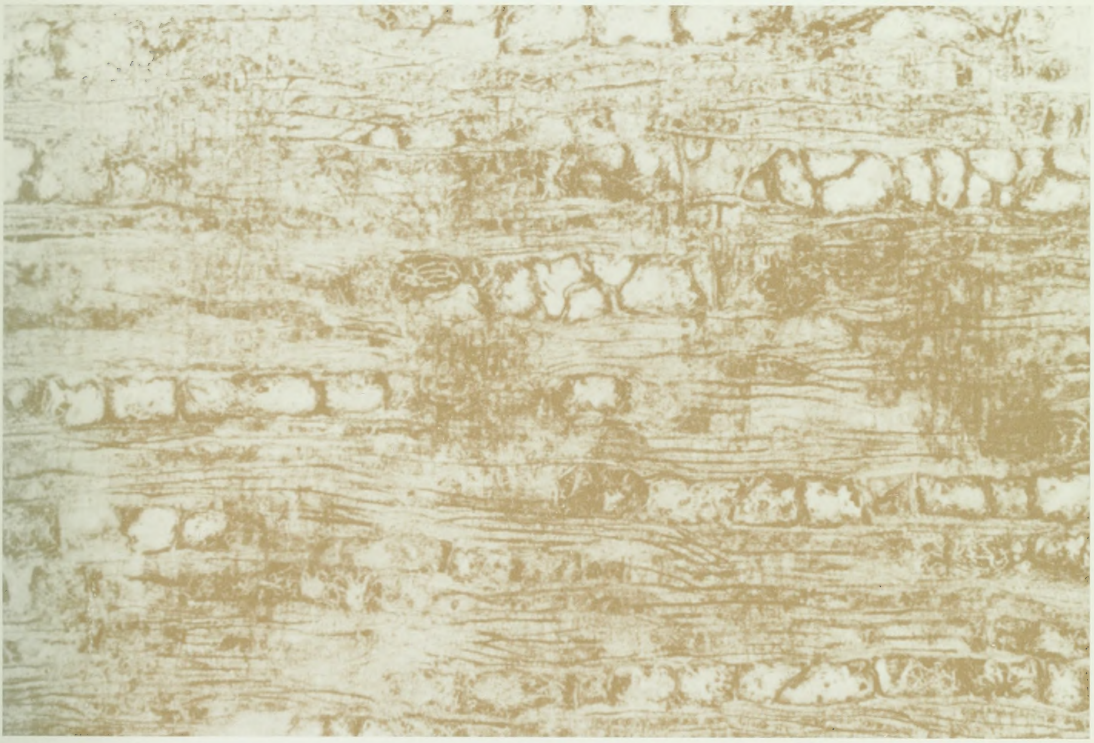

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A Hemphillian (Late Miocene) Mammalian Fauna from the Desert Mountains, West Central Nevada

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Abstract.—The Churchill Butte Local Fauna, a new fossil mammalian assemblage of Hemphillian (late Miocene) age, is now recognized from the "Coal Valley Formation" of the western Desert Mountains, Lyon County, Nevada. It is the first biostratigraphically datable fauna from the formation and consists of the following taxa: Canidae, gen. indet.; Felidae, genera indet. (two spp.); Proboscidea, fam. indet.; Tayassuidae, gen. indet.; Camelidae, genera indet. (at least two spp.); Rhinocerotidae, gen. indet.; Equidae, gen. indet.; Leporidae, gen. indet.; *Dipoides* cf. *D. wilsoni*; and *Parapliosaccomys oregonensis*.

In 1993, Ross Secord, then a student at the University of Nevada, Reno, discovered a locality (W. M. Keck Museum locality number P-0101) in the western Desert Mountains that yielded a small sample of fossil mammals. The locality occurs along the western flank of the Desert Mountains about 7 km southeast of Churchill Butte in Lyon County, Nevada. A subsequent field investigation of the locality by the authors has resulted in the discovery of additional mammal fossils. The vertebrate fossil assemblage from this locality is herein referred to as the Churchill Butte Local Fauna.

The purpose of this report is to: 1) document the mammalian taxa that comprise the new fauna; and 2) review the stratigraphic and geochronologic relations of the formation that yielded the fauna.

Methods

Measurements of larger mammal teeth and appendicular elements were taken with a vernier caliper to the nearest 0.1 mm, and those of smaller mammals were taken with an AO optical micrometer disc to the nearest 0.01 mm. All teeth were measured along their greatest anteroposterior and transverse dimensions. Metric abbreviation, dental terminology (except for those of *Dipoides* Jager 1835), and dental formulae follow standard usage. Dental terminology for *Dipoides* follows Stirton (1935). Upper teeth are indicated by uppercase letters and lower teeth by lowercase letters. All specimens are in the W. M. Keck Museum (WMK) at the Mackay School of Mines, University of Nevada, Reno. The locality section was measured using a Jacob's staff and Brunton transit to the nearest 0.25 m.

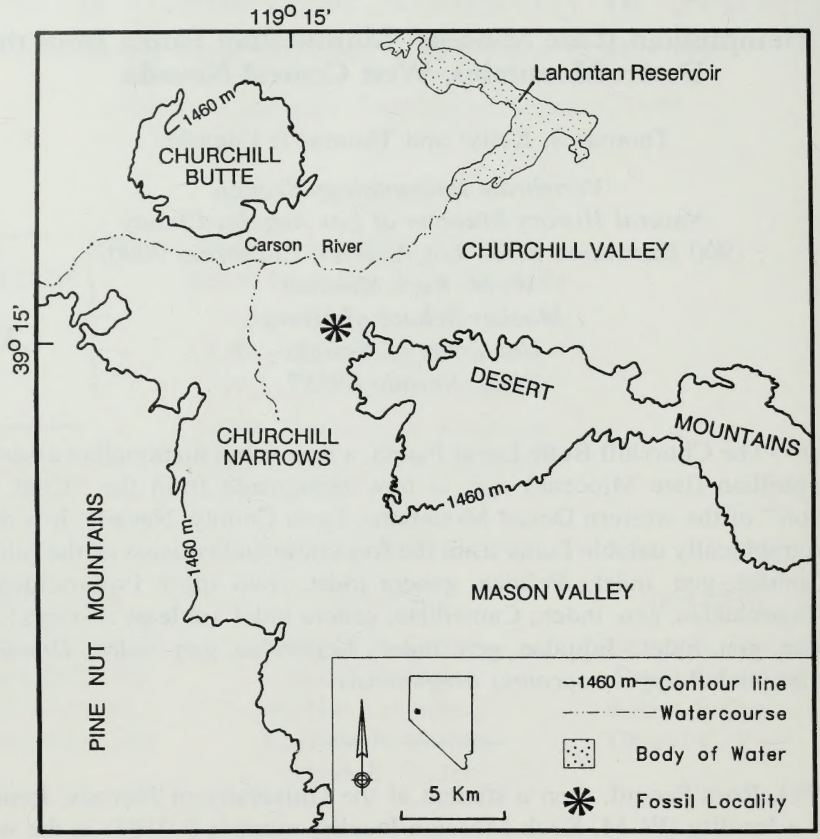

Fig. 1. Generalized map showing location of vertebrate fossil locality P-0101 on western flank of Desert Mountains near Churchill Butte.

Abbreviations are as follows: A-P, greatest anteroposterior dimension; d, deciduous; L, left; R, right; *s. s.*, *sensu stricto*; TR, greatest transverse dimension.

Geology and Occurrence of Fossils

Moore (1969) mapped outcrops of Tertiary sedimentary rocks in Lyon County that extend eastward from the northeast flanks of the Pine Nut Mountains across the Churchill Narrows area to the western flanks of the Desert Mountains. He also mapped sediments of similar lithology that outcrop further east along the north side of Mason Valley and in the Wildhorse Basin of the Desert Mountains. Kelly (1998) considered these rocks as correlatives of the type Coal Valley Formation of Gilbert and Reynolds (1973), but not as strict lithocorrelatives because they were probably deposited in a separate depositional basin from that of the type Coal Valley Formation. For this reason, Kelly (1998) referred to these rocks as "Coal Valley Formation".

The "Coal Valley Formation" of the Pine Nut Mountains-Churchill Narrows-Desert Mountains area consists of lacustrine and fluvial deposits of diatomite, siliceous shale, siltstone, mudstone, sandstone, and pebble conglomerate. The

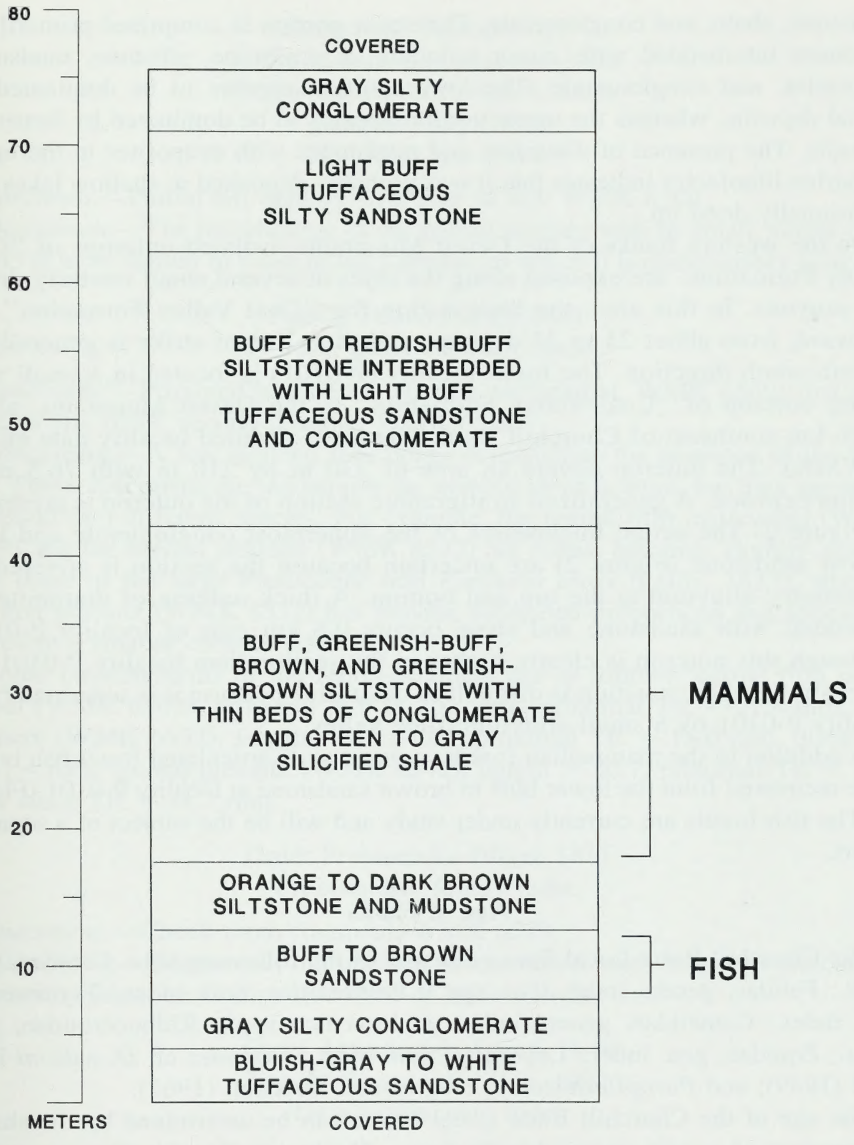

Fig. 2. Stratigraphic section of W. M. Keck Museum locality P-0101 showing occurrences of fossils within section.

sandstones and siltstones are commonly tuffaceous and often contain abundant fossilized rootlets. The formation unconformably overlies Miocene andesite interbedded with sedimentary deposits, probably a correlative of the Kate Peak Formation, and is unconformably overlain by late Pliocene to Pleistocene basalts and Quaternary alluvium (Moore 1969; Kelly 1995). Based on lithology, the formation can be roughly divided into a lower and upper portion. The lower portion is comprised primarily of sandstone interbedded with minor amounts of siltstone,

mudstone, shale, and conglomerate. The upper portion is comprised primarily of diatomite interbedded with minor amounts of sandstone, siltstone, mudstone, evaporites, and conglomerate. The lower portion appears to be dominated by fluvial deposits, whereas the upper portion appears to be dominated by lacustrine deposits. The presence of diatomite and mudstones with evaporites in the upper lacustrine lithofacies indicates that it was probably deposited in shallow lakes that occasionally dried up.

On the western flanks of the Desert Mountains, isolated outcrops of "Coal Valley Formation" are exposed along the sides of several small westerly-draining canyons. In this area, the beds within the "Coal Valley Formation" dip eastward, from about 25 to 33 degrees, and their line of strike is generally in a north-south direction. The fossil locality (P-0101) is located in a small west facing outcrop of "Coal Valley Formation" in the Desert Mountains, about seven km southeast of Churchill Butte (Figure 1; detailed locality data on file at WMK). The outcrop covers an area of 330 m by 210 m with 76.5 m of section exposed. A generalized stratigraphic section of the outcrop is presented in Figure 2. The actual thicknesses of the uppermost conglomerate and lowermost sandstone (Figure 2) are uncertain because the section is covered by Quaternary alluvium at the top and bottom. A thick outcrop of diatomite interbedded with sandstone and shale occurs 0.8 km east of locality P-0101. Although this outcrop is clearly higher in the section than locality P-0101, its exact stratigraphic position is difficult to determine because it is separated from locality P-0101 by a small alluvium filled valley.

In addition to the mammalian fossils, numerous disarticulated fossil fish bones were recovered from the lower buff to brown sandstone at locality P-0101 (Figure 2). The fish fossils are currently under study and will be the subject of a separate report.

Age of Fauna

The Churchill Butte Local Fauna consists of the following taxa: Canidae, gen. indet.; Felidae, genera indet. (two spp.); Proboscidea, fam. indet.; Tayassuidae, gen. indet.; Camelidae, genera indet. (at least two spp.); Rhinocerotidae, gen. indet.; Equidae, gen. indet.; Leporidae, gen. indet.; *Dipoides* cf. *D. wilsoni* Hibbard (1949); and *Parapliosaccomys oregonensis* Shotwell (1967).

The age of the Churchill Butte Local Fauna can be determined by the shared occurrences of certain taxa within the fauna. The beaver *Dipoides* first appears in the early Hemphillian and last occurs in the Blancan (Korth 1994). Most investigators generally regard the extinction of the Rhinocerotidae as one of the events to mark the end of the Hemphillian (Tedford *et al.* 1987). However, Madden and Dalquest (1990) reported finding a single fragment of a rhino tooth during screen washing of matrix from the Blancan Yellow Quarry, Scurry County, Texas (Beck Ranch Local Fauna). With the exception of this record, no other occurrences of the Rhinocerotidae in the Blancan are known (Prothero 1998). The geomyid *Parapliosaccomys oregonensis* was previously known only from the Hemphillian McKay Reservoir Fauna of Oregon. The combined presence of the Rhinocerotidae, *Dipoides*, and *Parapliosaccomys oregonensis* in the Churchill Butte Local Fauna indicates the fauna is Hemphillian (late Miocene) in age.

Systematic Paleontology

Class Mammalia Linnaeus, 1758

Order Carnivora Bowdich, 1821

Canidae Gray, 1821

?Canidae, gen. indet.

Specimen.—Partial left dentary with root of m3, WMK 6504.

Discussion.—The morphology of the partial dentary with its small, single-rooted m3 is most similar to those of the Canidae, to which it is questionably assigned.

Family Felidae Gray, 1821

Felidae, genera and spp. indet.

Specimens.—Proximal portion of left fifth metacarpal, WMK 6569; first phalanx, WMK 6532; second phalanx, WMK 6542.

Discussion.—A few isolated foot bones demonstrate the presence of the Felidae. These specimens are inadequate for generic identification, but they appear to represent two different species. For example, the partial fifth metacarpal (WMK 6569) and the second phalanx (WMK 6542) are robust and only slightly smaller than those of the large Pleistocene lion *Panthera atrox* (Leidy, 1853), whereas the first phalanx (WMK 6532) has slender, elongated proportions and appears to represent a smaller cheetah sized cat.

Some measurements of the felid specimens are as follows: partial fifth metacarpal (WMK 6569), proximal A-P = 20.1 mm, proximal TR = 21.8 mm; first phalanx (WMK 6532), length = 43.1 mm, proximal TR = 15.0 mm, distal TR = 11.4 mm; second phalanx (WMK 6542), length = 30.7, proximal TR = 14.5 mm, distal TR = 11.7 mm.

Order Proboscidea Illiger, 1811

Proboscidea, family indet.

Specimens.—Cheek tooth fragment, WMK 6579.

Discussion.—The enamel morphology of the cheek tooth fragment indicates it represents either the Gomphotheriidae or Mammutidae.

Order Artiodactyla Owen, 1848

Family Tayassuidae Hay, 1902

Tayassuidae, gen. indet.

Specimen.—Lower cheek tooth fragment, WMK 6512.

Discussion.—The lower cheek tooth fragment is inadequate for generic identification, but indicates the presence of a peccary in the fauna.

Family Camelidae Gray, 1821

Camelidae, genera and spp. indet.

Specimens.—Associated broken LP4-M2 WMK 6552; associated partial dRP4 and partial dLP4, WMK 6514, WMK 6515; partial lower left incisor, WMK 6516; distal humerus, WMK 6501; partial distal radius, WMK 6507; scaphoid carpal, WMK 6540; scaphoid carpal, WMK 6576; partial ?scaphoid carpal, WMK 6573; unciform carpal, WMK 6559; accessory carpal, WMK 6511; accessory carpal, WMK 6571; partial accessory carpal, WMK 6557; astragalus, WMK 6506; cuboid

tarsal, WMK 6553; cuboid tarsal, WMK 6565; partial cuboid tarsal, WMK 6578; entocuneiform tarsal, WMK 6574; distal metapodial condyle, WMK 6503; distal metapodial condyle, WMK 6513; first phalanx, WMK 6505; partial first phalanx, WMK 6510; partial first phalanx, WMK 6508; partial first phalanx, WMK 6572; partial first phalanx, WMK 6538; partial first phalanx, WMK 6563; partial first phalanx, WMK 6577; partial second phalanx, WMK 6541;

Discussion.—The camel material consists of numerous isolated appendicular elements and a few fragmentary teeth that can be divided into three distinct size groups: a small-sized camel (WMK 6503, WMK 6505, WMK 6506, WMK 6510, WMK 6511, WMK 6514, WMK 6515, WMK 6516, WMK 6538, WMK 6540, WMK 6541, WMK 6557, WMK 6559, WMK 6563, WMK 6573, WMK 6574, WMK 6576, WMK 6577, WMK 6578), similar in size to *Hemiauchemia vera* (Matthew, 1909, in Matthew and Osborn 1909); a medium-sized camel (WMK 6501, WMK 6507, WMK 6508, WMK 6513, WMK 6552, WMK 6565, WMK 6571, WMK 6572), similar in size to *Pliauchenia* Cope (1875); and a very large camel (WMK 6553), similar in size to *Megatylopus* Matthew and Cook (1909). The broken teeth are of typical camelid morphology and not complete enough to allow generic identification. The three size groups appear to indicate that three camel species are present in the fauna. However, some species of camels are known to exhibit a fair degree of sexual dimorphism and, therefore, it is possible that the small and medium-sized camel elements could represent the same species. The large-sized camel specimens are significantly larger than the small and medium-sized camel specimens and can be confidently regarded as representing a different species. Thus, at least two, possibly three, species of camels are present in the fauna.

Measurements of selected specimens demonstrate the three size groups. Measurements of the small-sized camel specimens are as follows: broken dLP4 (WMK 6514), A-P = 17 mm estimated, TR = 14–15 mm estimated; astragalus (WMK 6506), height = 42.0 mm, greatest width = 24.3 mm; distal metapodial condyle (WMK 6503), A-P = 23.5 mm, TR = 18.5 mm; first phalanx (WMK 6505), length = 70.5 mm, proximal TR = 21.4 mm, distal TR = 17.0 mm. Measurements of the medium-sized camel specimens are as follows: damaged P4-M2 (WMK 6552), P4 A-P = 14.9 mm, M1 A-P (broken) = 27.9 mm, M2 (broken) A-P = 28.9 mm; distal humerus (WMK 6501), A-P across condyles = 53.3 mm, TR across condyles = 52.8 mm; distal radius (WMK 6507), greatest TR across distal articular surface = 53–54 mm estimated; distal metapodial condyle (WMK 6513), A-P = 30.9 mm, TR = 22.8 mm; proximal first phalanx (WMK 6572), proximal A-P = 28.3 mm, proximal TR = 29.3 mm. Measurements of the large-sized camel specimen are as follows: left cuboid tarsal (WMK 6553), height = 42.0 mm, A-P = 61.6 mm, TR = 42.0 mm.

Order Perissodactyla Owen, 1848
Family Rhinocerotidae Owen, 1845
Rhinocerotidae, gen. indet.

Specimens.—Lower cheek tooth fragment, WMK 6561; lower cheek tooth fragment, WMK 6562.

Discussion.—The cheek tooth fragments can only be identified as belonging to

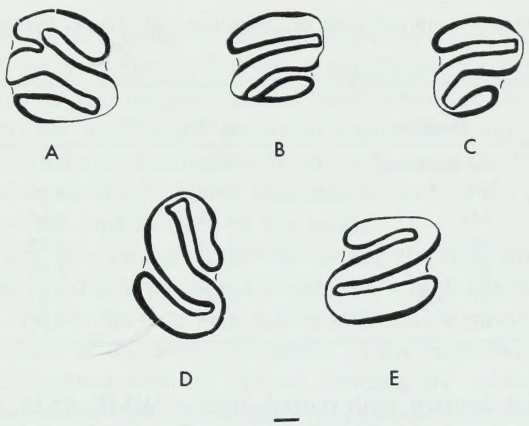

Fig. 3. *Dipoides* cf. *D. wilsoni* Hibbard (1949) of Churchill Butte Local Fauna; A, RP4, WMK 6528; B, LM1, WMK 6523; C, LM3, WMK 6529; D, Lp4, WMK 6527; E, Rm1 or 2, WMK 6526. All occlusal views with anterior up; A and D, lateral to left; B, C, and E, lateral to right. Scale = 1 mm.

the Rhinocerotidae. The presence of a rhino in the fauna indicates that the fauna is probably no younger than Hemphillian.

Family Equidae Gray, 1821
Equidae, gen. indet.

Specimens.—Deciduous upper premolar fragment, WMK 6566; lower cheek tooth fragment, WMK 6567; lower cheek tooth fragment (preflexid), WMK 6568; first phalanx, WMK 6509.

Discussion.—Although the equid specimens can only be identified to family, a few characters can be distinguished. The cement is moderately thick on the deciduous upper premolar fragment (WMK 6566). The preflexid of the lower cheek tooth fragment (WMK 6568) has a simple occlusal enamel morphology, similar to those of *Dinohippus* Quinn (1955) and *Pliohippus* Marsh (1874). As compared with other Hemphillian horses, the slightly crushed, first phalanx (WMK 6509) is moderate in size, measuring 55.0 mm in length, 30.5 mm proximal TR, and 31.1 mm distal TR.

Order Lagomorpha Brandt, 1855
Family Leporidae Gray, 1821
Leporidae, gen. indet.

Specimens.—Partial upper cheek tooth, WMK 6530; calcaneum, WMK 6517; partial calcaneum, WMK 6518; partial calcaneum, WMK 6519.

Discussion.—The rabbit specimens were only identified to family.

Order Rodentia Bowdich, 1821
Family Castoridae Gray, 1821
Genus *Dipoides* Jager, 1835
Dipoides cf. *D. wilsoni* Hibbard, 1949
Figure 3, Table 1

Specimens.—Partial maxilla with partial incisor and LP4-M1, WMK 6523; RP4, WMK 6528; LM3, WMK 6529; partial right dentary with base of incisor,

Table 1. Measurements (in mm) of teeth of *Dipoides* cf. *D. wilsoni* Hibbard (1949) from Desert Mountains.

Specimen number	Position	A-P	TR	Crown height
WMK 6523	P4 (unworn)	3.65	3.65	—
WMK 6528	P4	4.63	4.50	14.4
WMK 6523	M1	3.52	3.60	10.4
WMK 6529	M3	3.75	3.35	10.2
WMK 6527	p4	5.10	3.55	16.3
WMK 6526	m1 or 2	3.80	3.97	14.3
WMK 6522	m2	3.95	3.91	—

WMK 6524; partial dentary with partial incisor, WMK 6525; Lp4, WMK 6527; partial dentary with Lm2, WMK 6522; Rm1 or 2, WMK 6526; associated cheek tooth fragments, WMK 6534.

Discussion.—The small sample of *Dipoides* from the Desert Mountains consists of isolated teeth, partial dentaries with broken incisors and a m2, and a partial maxilla with P4-M1. All of the cheek teeth are rootless and hypsodont. The transverse widths are usually greater anteriorly in the upper molars, whereas in P4 and the lower cheek teeth the transverse widths are usually greater posteriorly. Cement is present in the flexi and flexids of the upper and lower cheek teeth, respectively.

Two P4's are represented in the sample; an unworn P4 (WMK 6523) in the process of erupting and a moderately worn P4 (WMK 6528). The unworn P4 (WMK 6523) exhibits the following characters: 1) a paraflexus, mesoflexus, and hypoflexus are present; 2) multiple small cusps are present on the mesostyle; and 3) several small cusps are present on the paracone. The morphology of the unworn P4 is not specifically diagnostic because the unworn P4 occlusal pattern is very similar in all species of *Dipoides* (Shotwell 1955). The moderately worn P4 (WMK 6528) exhibits the following characters: 1) a shallow, but persistent, paraflexus is present that extends lingually across the occlusal surface to almost meet with the deep hypoflexus, resulting in a narrow isthmus connecting the anterior loph to the middle loph; 2) a metaflexus and metastria are lacking on the occlusal surface and labial side of the posterior loph, respectively; 3) the mesoflexus extends lingually almost completely across the occlusal surface, almost isolating the posterior loph from the middle loph; and 4) the parastria, mesostria, and hypostria extend down the entire depth of the tooth.

The M1 (WMK 6523) is in early wear and is characterized by having the following: 1) a general "S" shaped occlusal pattern; 2) a paraflexus and metaflexus are lacking; 3) the hypoflexus extends labially across almost the entire occlusal surface, with its labial termination squared off, giving the hypoflexus an elongated rectangular shape; 3) the mesoflexus extends posterolingually across the occlusal surface, almost uniting with the lingual enamel wall, resulting in a narrow enamel connection of the middle loph to the posterior loph (this connection probably widens with wear); and 4) the hypostria and mesostria extend down the entire depth of the tooth.

The M3 (WMK 6529) is characterized by having the following: 1) a paraflexus and metaflexus are lacking; 2) the hypoflexus extends labially almost completely

across the occlusal surface, with its labial termination squared off and its sides nearly parallel; 3) the mesoflexus extends lingually across the occlusal surface, where it almost meets the lingual enamel wall, resulting in a narrow enamel connection between the middle and posterior lophs (however, at the base of the tooth the mesoflexus lingual termination is not so close to the lingual enamel wall and it is no longer squared off, but is bifurcated); and 4) the hypostria and mesostria extend down the entire depth of the tooth.

The p4 (WMK 6527) is characterized by having the following: 1) a paraflexid is absent, but a faint, vestigial parastriid is present, which extends down the entire depth of the tooth and results in a very minor indentation along the lingual aspect of the occlusal surface of the anterior lophid; 2) the mesoflexid extends anterolabially across the occlusal surface, almost abutting the labial enamel wall, resulting in anteroposteriorly oriented anterior and middle lophids; 3) the hypoflexid extends lingually across about three-quarters of the occlusal surface wherein it turns anterolingually and further extends to end in a rounded terminus close to the lingual enamel wall; and 4) the mesostriid and hypostriid extend down the entire depth of the tooth.

The lower molars (WMK 6522, WMK 6526) are characterized by having the following: 1) simple "S" shaped occlusal patterns, with only mesoflexids and hypoflexids present; 2) the mesoflexids and hypoflexids have nearly parallel sides and rounded labial and lingual termini, respectively; and 3) the mesostriids and hypostriids extend down the entire depths of the teeth.

Measurements of the *Dipoides* specimens are presented in Table 1.

Species of *Dipoides* are differentiated primarily by size and cheek teeth occlusal morphologies (Wilson 1934; Stirton 1935; Shotwell 1955; Baskin 1979). A fair degree of intraspecific variation occurs in the cheek teeth occlusal patterns of *Dipoides*, so that species are often defined by frequencies of particular occlusal patterns rather than by the absolute presence or absence of a particular dental character (Shotwell 1955). The amount of intraspecific variation in the cheek teeth occlusal patterns of the Desert Mountains *Dipoides* cannot be determined because of the small sample size. The Desert Mountains specimens are regarded as belonging to one species because they all appear to be about the same size and all were recovered from a single locality. In fact, based on the degree of wear, some of the isolated teeth may represent the same individual.

Even though the number of *Dipoides* specimens from the Desert Mountains is small, they exhibit a distinctive suite of dental characters that can be compared with other recognized species of *Dipoides*. Six North American species of *Dipoides* are currently recognized: *D. stirtoni* Wilson (1934); *D. williamsi* Stirton (1936); *D. rexroadensis* Hibbard and Riggs (1949); *D. wilsoni* Hibbard (1949); *D. smithi* Shotwell (1955); and *D. vallicula* Shotwell (1970). One other species that was originally assigned to *Dipoides*, *D. intermedius* Zakrzewski (1969), has recently been referred to *Procastoroides* Barbour and Schultz (1937) by Repenning et al (1995). The Desert Mountains *Dipoides* differs from *D. stirtoni* by having the following characters: 1) significantly smaller in size; 2) a P4 metaflexus is lacking; and 3) a p4 paraflexid is lacking. It differs from *D. williamsi* by having the following characters: 1) slightly smaller in size; 2) a P4 paraflexus is present; and 3) a p4 paraflexid is lacking. It differs from *D. rexroadensis*, a poorly known species (Hibbard and Riggs 1949; Woodburne 1961; Zakrzewski 1969), by its

much smaller size. It differs from *D. wilsoni* by having the following characters: 1) a P4 paraflexus is present; and 2) the lower molar flexids have rounded rather than flattened terminations and are not as closely abutted to the opposing enamel walls. It differs from *D. smithi* by having the following characters: 1) significantly smaller in size; and 2) the P4 anterior loph is slightly less inflated and relatively narrower. It differs from *D. vallicula* by having the following characters: 1) the molar flexi and flexids are relatively narrower; 2) the P4 paraflexus and hypoflexus are slightly overlapping and do not abut, resulting in an oblique isthmus instead of an anteroposteriorly directed isthmus; and 3) a p4 paraflexid is lacking. It differs from *Procastoroides intermedius* by having the following characters: 1) much smaller size; 2) less hypsodont cheek teeth; and 3) the M3 lacks a metaflexus and metastria. In addition to the six recognized species of *Dipoides*, previous investigators have referred a number of specimens from various formations to *Dipoides*. Stirton (1935) referred specimens from the Rattlesnake Formation of Oregon and the Thousand Creek Beds of Nevada to *Dipoides*. The Desert Mountains form differs from the Rattlesnake and Thousand Creek forms by its much smaller size and lack of a p4 paraflexid. Macdonald (1959) referred specimens from the Coal Valley Formation of Smith Valley, Nevada, to *Dipoides*. The Desert Mountains form differs from the Smith Valley form by having the following characters: 1) slightly smaller in size; 2) a P4 paraflexus present 3) a P4 metaflexus is lacking; and 4) a p4 paraflexid is lacking.

Although the differences noted above indicate the Desert Mountains *Dipoides* specimens may represent a new species, they also exhibit certain similarities to *D. wilsoni* and specimens referred by Shotwell (1955) to *D.* cf. *D. wilsoni* from the Malheur River area, Oregon. The Desert Mountain teeth are similar to those of *D. wilsoni* by having the following characters: 1) small size; 2) relatively hypsodont cheek teeth; and 3) a p4 with a weak or absent paraflexid. The size and overall occlusal patterns of the Desert Mountains *Dipoides* teeth are morphologically most similar to those of certain specimens referred to *D.* cf. *D. wilsoni* from the Malheur River area, including P4's with paraflexi and parastriae that result in isthmuses between the anterior and posterior lophs, and p4's that lack paraflexids. The Desert Mountains form differs from *D.* cf. *D. wilsoni* from the Malheur River area by having the lower molar flexid terminations not squared off, but more rounded.

A much larger sample of *Dipoides* from the Desert Mountains is needed before this form can be fully characterized. Until such time, the Desert Mountain specimens are herein referred to *Dipoides* cf. *D. wilsoni*.

In North America, *Dipoides* has its first occurrence in the early Hemphillian (late Miocene) and its last occurrence in the Blancan (Pliocene) (Tedford *et al.* 1987; Korth 1994). The presence of *Dipoides* in the Churchill Butte Local Fauna indicates the fauna is no older than Hemphillian.

Family Geomyidae Gill, 1872
Genus *Parapliosaccomys* Shotwell, 1967
Parapliosaccomys oregonensis Shotwell, 1967
Figure 4

Specimen.—Rp4, WMK 6531.

Discussion.—The slightly worn Rp4 is subhypsodont with a basic two col-

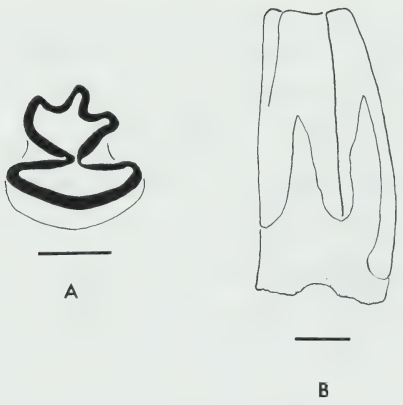

Fig. 4. *Parapliosaccomys oregonensis* Shotwell (1967) of Churchill Butte Local Fauna: Rp4, WMK 6531, A—occlusal view, anterior up, lateral to right, B—medial view, anterior left. Scales for A and B = 1 mm.

umned structure (anterior and posterior lophids). Two distinct roots are present that are still partially open at their bases. The anterior lophid has a distinctive trefoil occlusal outline. This occlusal pattern would rapidly disappear with wear because it only extends down the anterior lophid about 1.3 mm from the crown, after which the anterior lophid would assume a simple ovoid occlusal pattern with a strong central union to the posterior lophid. Dentine tracts are present on the labial and lingual aspects of the anterior and posterior columns. The tracts extend up from the base of the crown, ranging in length from 1.5 mm to 3.3 mm, but do not reach the occlusal surface during early wear. In later wear, about half way down the tooth, the dentine tracts would interrupt the lateral occlusal enamel outlines of the anterior and posterior lophids. Measurements of WMK 6531 are as follows: occlusal A-P = 1.27 mm, occlusal anterior TR = 1.35 mm, occlusal posterior TR = 1.87 mm, crown height = 5.3 mm.

The p4 is indistinguishable from those of *Parapliosaccomys oregonensis* from McKay Reservoir, Oregon, and it is tentatively assigned to this species. It differs from those of the closely related *Pliosaccomys* Wilson (1936) by its relatively greater hypsodonty and the presence of dentine tracts.

Three species have been previously assigned to *Parapliosaccomys*: *P. oregonensis* of the Hemphillian McKay Reservoir Fauna of Oregon; *P. hibbardi* (Storer, 1973) from the Clarendonian WaKeeney Local Fauna of Kansas; and *P. annae* Korth (1987) from the Barstovian Valentine Formation of Nebraska. Recently, Akersten (1988) and Korth (1994) questioned the assignment of *P. hibbardi* and *P. annae* to *Parapliosaccomys* because of differences between the lower premolars of these species and those of the type species *P. oregonensis*. It appears that *P. hibbardi* and *P. annae* are generically distinct from *P. oregonensis* and should not be included in *Parapliosaccomys s. s.* As such, *Parapliosaccomys* is a monotypic genus restricted to the Hemphillian. The presence of *P. oregonensis* in the fauna from the Desert Mountains indicates the fauna is Hemphillian in age.

Summary

The "Coal Valley Formation" of the western Desert Mountains, Lyon Country, Nevada, has yielded a new fossil mammalian assemblage, the Churchill Butte

Local Fauna. The fauna consists of the following taxa: Canidae, gen. indet.; Felidae, genera indet. (two spp.); Proboscidea, fam. indet.; Tayassuidae, gen. indet.; Camelidae, genera indet. (at least two spp.); Rhinocerotidae, gen. indet.; Equidae, gen. indet.; Leporidae, gen. indet.; *Dipoides* cf. *D. wilsoni*; and *Parapliosaccomys oregonensis*. The shared occurrences of *Dipoides, Parapliosaccomys oregonensis*, and Rhinocerotidae indicate that the fauna is Hemphillian (late Miocene) in age. The Churchill Butte Local Fauna is the first biostratigraphically datable fauna from the "Coal Valley Formation" of the western Desert Mountains.

Exposures of "Coal Valley Formation" can be traced westward from the western flanks of the Desert Mountains across the Churchill Narrows area to the northeastern flanks of the Pine Nut Mountains in Lyon County, Nevada (Moore 1969; Kelly 1998). The discovery of the Churchill Butte Local Fauna indicates that the "Coal Valley Formation" of the Pine Nut Mountains-Churchill Narrows-Desert Mountains area was deposited, at least in part, during the Hemphillian (late Miocene). Additional exposures of "Coal Valley Formation" occur north and northeast of the Pine Nut Mountains-Churchill Narrows-Desert Mountains area as follows: 1) along the southeastern flanks of the Virginia Range, Lyon Country; 2) in the central Virginia Range, Storey Country; and 3) in the vicinity of the communities of Mogul and Verdi, Washoe County (Kelly 1998). In the Mogul-Verdi area, the "Coal Valley Formation" is about 900 m thick and has been radiometrically and biostratigraphically dated from the Clarendonian (late Miocene) to the latest Hemphillian or earliest Blancan (early Pliocene) (Axelrod 1958, 1962; Bonham 1969; Kelly 1998). In the Chalk Hills area of the central Virginia Range, the "Coal Valley Formation" is about 850 m thick and, based on biostratigraphic data and radiometric dates on underlying and overlying strata (Bonham 1969; Kelly 1998), was deposited from the Clarendonian to the late Hemphillian or early Blancan. Along the southeastern flanks of the Virginia Range, the "Coal Valley Formation" is about 228 m thick and has yielded the Churchill Valley Local Fauna of probable Clarendonian age from the lower 92 m of the formation (Kelly 1998). In the Churchill Narrows area, the Churchill Narrows Site has yielded a mammalian assemblage of undetermined age from near the base of the "Coal Valley Formation" (Kelly 1998). The thickness of the "Coal Valley Formation" in the Pine Nut Mountains-Churchill Narrows-Desert Mountains area has not been determined, but appears to be thickest along the northeastern flanks of the Pine Nut Mountains, where at least several hundred meters are exposed. From the east side of the Churchill Narrows to the western flanks of the Desert Mountains, the formation thins, so that in the vicinity of locality P-0101, the formation is only about 150 m thick.

The "Coal Valley Formation" of west central Nevada may have been deposited in two or possibly three different depositional basins. The thick deposits in Mogul-Verdi area and the central Virginia Range probably represent two separate depositional basins. A third depositional basin may have been centered in the area now exposed along the northeastern flanks of the Pine Nut Mountains. However, because the "Coal Valley Formation" exhibits a general eastward thinning from the central Virginia Range across the southern flanks of the Virginia Range and southeastward to the Pine Nut Mountains-Churchill Narrows-Desert Mountains area, it is also possible that these areas represent a single depositional basin.

The composition of the Churchill Butte Local Fauna provides evidence of the

paleoenvironmental setting during the time of deposition at locality P-0101. The fauna includes browsers (a bunodont proboscidean and Rhinocerotidae), grazers (Equidae, Camelidae, and Leporidae), and aquatic animals (fish and the beaver *Dipoides*). This faunal combination indicates the paleoenvironment was probably characterized by grasslands or open woodlands with thicker woodlands occurring along perennial streams or small lakes. The streams or lakes probably supported riparian vegetation suitable for browsing animals, whereas, further from the watercourses, grasslands or open woodlands supported grazing animals. The presence of tuffaceous deposits at locality P-0101 and throughout the "Coal Valley Formation" of the Pine Nut Mountains-Churchill Narrows-Desert Mountains area indicates that the area was periodically supplied with volcaniclastic debris of epiclastic and airfall origin.

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Fossil Wood from the Middle Miocene Conejo Volcanics, Santa Monica Mountains, California

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Abstract.—Evidence that the upper Conejo Volcanics erupted subaerially is confirmed by the discovery of fossil wood preserved in a ~13.5 Ma tuff breccia exposed on the northern flank of the Santa Monica Mountains, California. This middle Miocene wood represents a low montane geoflora of hardwoods and conifers that lived at elevations greater than 1,300 m. Ponderosa Pine, Douglas Fir, Incense Cedar, and specimens from the dicotyledonous families Fagaceae (evergreen and live oaks), Rosaceae (mountain mahogany), and Rhamnaceae (mountain lilac) have been identified by thin section analysis. Preservation of this wood varies from amorphous clayey limb casts to splintered surfaces and detailed cell features. This is the first record of fossil trees in a tuff breccia from the Los Angeles basin region.

In 1995, development of a 70-acre construction project in the Thousand Oaks area northwest of Los Angeles exposed the middle Miocene Upper Topanga Formation and the underlying Conejo Volcanics. The volcanic units form ridges in the Santa Monica Mountains and represent a series of eruptions that commenced as submarine basalt flows about 16 Ma and concluded as subaerial lava flows and explosive lahars about 13.5 Ma (Yerkes and Campbell 1979).

Site mitigation required paleontologists to monitor the excavation of the Upper Topanga marine sandstones exposed along the northern portion of the project. As the monitors were crossing volcanic material to reach the sandstone, they discovered petrified wood fragments and two logs in tuff breccia. Grading operations were temporarily diverted while paleontologists determined the extent of the fossil wood and recovered specimens. Thin sections of these specimens show that preservation varies from detailed cell features to no identifiable features.

Site

The Conejo wood was recovered 65 km northwest of Los Angeles in the City of Westlake Village, north of California State Freeway 101, east of Lindero Canyon Road, and south of Thousand Oaks Boulevard (Fig. 1A). The 70-acre commercial/residential development is in a valley bounded on the north by hills of the Monterey Formation and on the south by the Conejo Volcanics. Extending east/west across the center of the valley floor is a small ridge that separates the volcanic rocks exposed along the south flank from the sandstone of the Upper Topanga Formation exposed to the north. As construction equipment removed colluvium, sandstone, and tuff breccia from the site, fossil wood fragments were

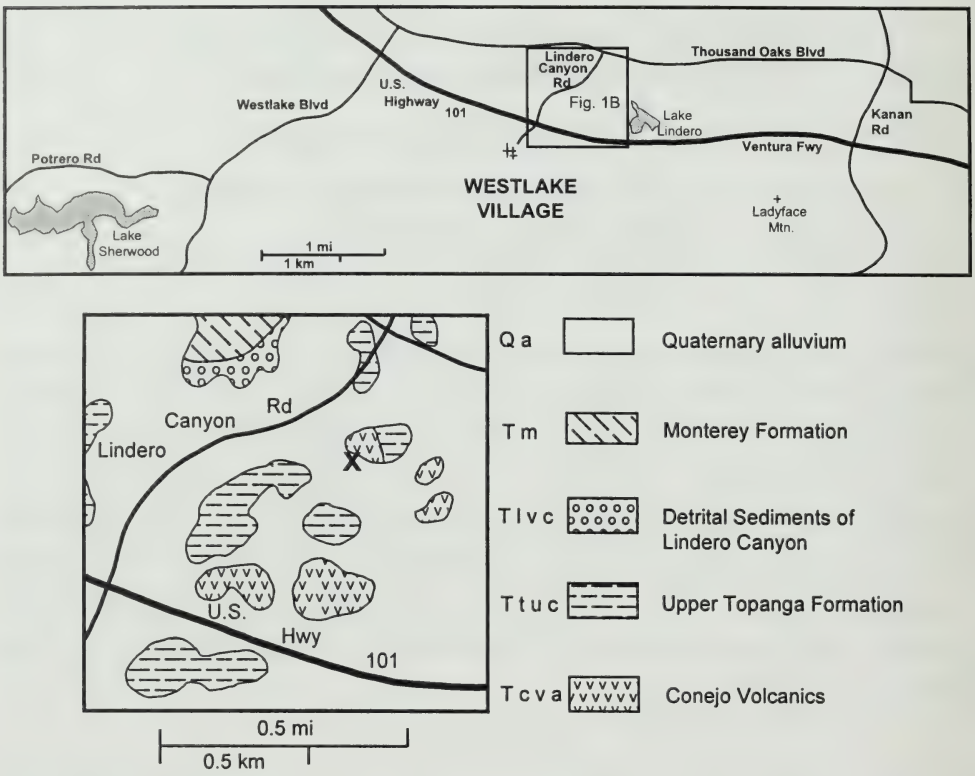

Fig. 1. Maps of the study area in the City of Westlake Village, Los Angeles County. A. Location map. Position of Fig. 1B outlined. B. Geologic map after Dibblee and Ehrenspeck (1993a). The "X" indicates the fossil wood site.

exposed across a 100-m^2 area along the southern flank of the ridge (Fig. 1B). Two broken logs were found encased in the tuff unit southwest of the ridge. This concentration of middle Miocene fossil wood may not be unique to the area. Local residents have reported that reworked fossil wood occurs throughout the Thousand Oaks region in the upper Conejo Volcanics and overlying Upper Topanga and Monterey Formations. [Note: The stratigraphic nomenclature of Dibblee and Ehrenspeck (1993a) is used here; Yerkes and Campbell (1979) refer to the latter two formations as the Calabasas and Modelo Formations respectively.]

Geologic Environment

The Conejo Volcanics lie between the Lower Topanga and Upper Topanga Formations (Dibblee and Ehrenspeck 1993a; Fig. 2) and include up to 2 km of extrusive basaltic flow breccias, flow and pillow lavas, andesite and tuff breccias, dacite breccias, and a variety of intrusive forms that have been described by Dibblee and Ehrenspeck (1993b). The lower portions of the volcanic sequence were formed in a marine environment, indicated by an abundance of pillow lavas, pillow breccias, and occasional layers of fossil oyster debris. Higher in the sequence, the rocks were deposited in a subaerial environment and include laharic breccias, fluvial and alluvial fan breccia-conglomerates, volcanic bombs (Dibblee and Ehrenspeck 1993b), and the fossil wood described in this paper. K-Ar dates,

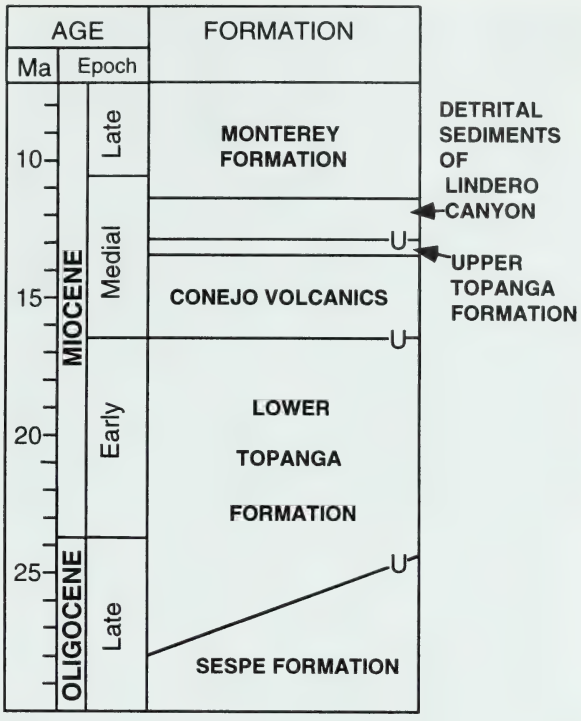

Fig. 2. Chronostratigraphic diagram of the rock units in the western Santa Monica Mountains based on the nomenclature of Dibblee and Ehrenspeck (1993a). "U" represents an unconformable contact.

determined by Turner (1970) and Yerkes and Campbell (1979) on plagioclase grains separated from samples collected throughout the volcanic section, range from 16.0 ± 0.6 to 13.5 ± 0.9 Ma (recalculated to new IUGS constants: Dalrymple 1979). Although the wood-containing tuff has not been dated, its occurrence at the top of the volcanic sequence suggests that it was deposited approximately 13.5 Ma.

In the project area, the volcaniclastic rocks containing the fossil wood have been mapped by Dibblee and Ehrenspeck (1993a) as part of an andesite flow and tuff breccia unit. This gently north-dipping unit occurs at the top of the volcanic sequence and is overlain conformably by marine clastic rocks of the Upper Topanga Formation. An anticline has been mapped east of the wood site; however, no attitudes could be measured in the immediate sample area.

Dibblee and Ehrenspeck (1993a) described these volcaniclastic units as ranging "from tan to light brown, massive, coherent, fine-grained feldspathic rock to less coherent, somewhat darker andesite breccia . . . composed of unsorted angular fragments in coherent matrix of same rock; deposited subaerially (?) as laharic flows." A laharic flow or lahar is a volcanic debris flow in which air-borne volcanic material that accumulates on the slopes of an active volcano becomes saturated with water and is mobilized, similar to lahars observed during the 1980 eruption of Mount St. Helens. Lahars can be mobilized during volcanic eruptions or long afterward and thus can be either warm or cold. In the case of the Conejo

lahars, the mobilizing event was probably heavy rainfall. The source of the lahars may occur 10 to 12 km to the west where possible dacite and andesite volcanic centers crop out near Lake Sherwood. Tuff deposits from these centers have been traced eastward beyond Lindero Canyon and Ladyface Mountain (Dibblee and Ehrenspeck 1993a).

The tuff breccia, exposed during development, is composed of rounded lapilli and larger flow clasts in a fine-grained ash matrix. It is unsorted and poorly bedded. Thin sections of the matrix rock show that the material consists of euhedral phenocrysts of abundant, concentrically-zoned plagioclase and subordinate dipyramidal quartz and biotite set in an altered, possibly devitrified, matrix. The phenocrysts exhibit pervasive jigsaw fractures, and some occur in aggregates. The fracturing, observed in virtually all the thin section crystals, is a typical feature of hydroclastic deposits produced by lahars. At least a third, and possibly as many as half, of the phenocrysts are complete. This, combined with their angular shape and the unsorted and unbedded nature of the deposit, suggests that the matrix is a primary, not reworked, pyroclastic deposit.

The tuff samples contain oblong inclusions 1 to 5 cm in length that are composed of quartz and sanidine (?) crystals set in smectite and possibly zeolite. These areas originally may have been pumice lapilli. Also present are spherical voids into which large zeolite laths have grown. A uniform isotropic substance, observed microscopically, may be kaolinitic clay with lesser amounts of small, possibly collapsed, pumice fragments, crystals of plagioclase and quartz, and lapilli-sized clasts of lava, possibly rhyodacite. These microscopic characteristics and field analyses of the volcanic matrix encasing the fossil wood confirm that the rock was deposited as a lahar.

Field Collection

The resistance of the tuff breccia limited the amount of wood that could be salvaged, and the collection represents an incomplete geoflora. Fossil coniferous and dicotyledonous woods were concentrated along the southern flank of an andesite ridge. The wood fragments appear to have been tumbled and worn. The surfaces of two logs found west of the fragments are splintered and have retained twig nodes.

A 170 cm long section of a Ponderosa pine log was removed before recovery operations were halted. The greatest diameter of the fossil pine is 36 cm (Fig. 3A). Depending upon the quality of soil, Ponderosa pines today can attain diameters greater than 45 cm in 75 to 150 years (Hughes and Dunning 1949). This suggests that the tree was less than 75 years in age when it was caught in the lahar.

The branch nodes and the splintered edges on the pine are unusually well preserved (Fig. 3B). A reddish sandy sediment, not occurring elsewhere in the tuff deposits, was plastered on one side of the log. R. B. Waitt (pers. comm. 1997) noted that during the 1980 eruption of Mount St. Helens, Washington, and the 1986 eruption of Augustine Volcano, Alaska, trunks and limbs of trees caught in lahars and cool pyroclastic flows show little or no charring and are commonly bruised, splintered, and sometimes shredded. None of the Conejo wood shows evidence of charring.

A portion of an oak log, 31 cm in diameter and 175 cm long, was recovered

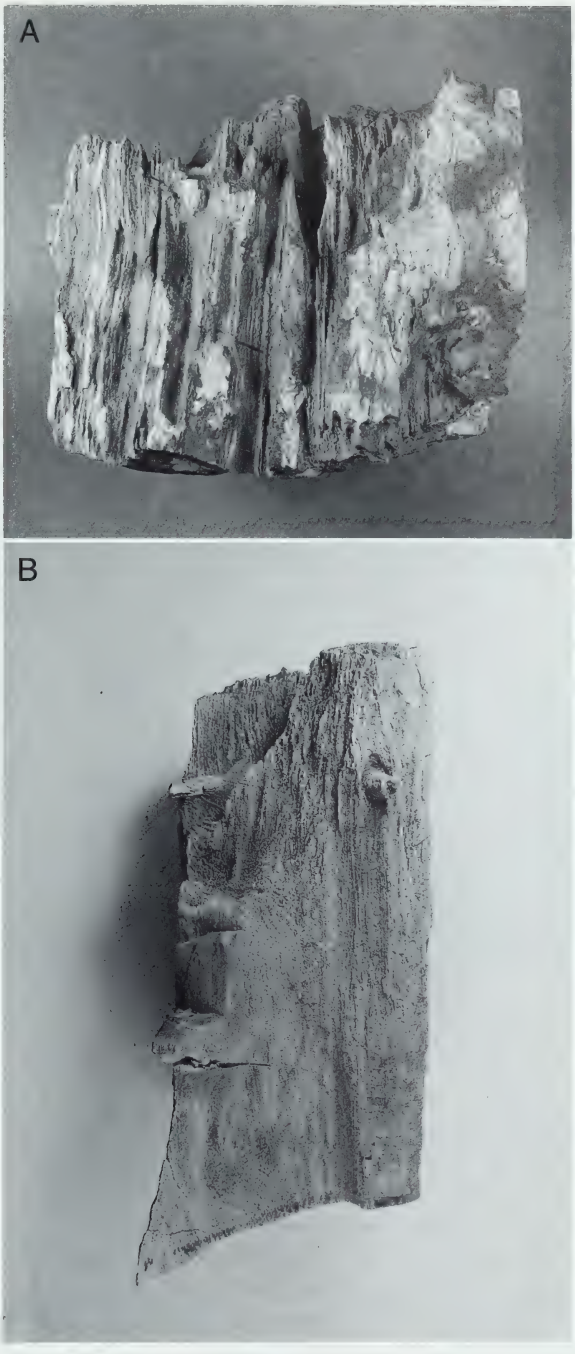

Fig. 3. Fossil wood. A. Splintered and abraded section of fossil pine log, DMW 615. Width is 150 mm. B. Fossil pine limb with broken branch nodes, DMW 615. Width is 85 mm.

4 m north of the pine. Both logs were inclined relative to the horizon. Unlike the pine that was abraded and had no bark, the broken oak log has retained its furrowed bark. The complete dimensions of the oak and pine logs could not be measured before they were buried by construction activities.

Sixteen m east of the two logs, three broken oak branches and numerous wood fragments were found. The branches are 28 to 30 cm in length and 5.5 cm in width. A polished cross section of branch CS 971 shows the trace of a stem and faint growth rings, rays, and bark. A cluster of wood fragments found south of the oak branches contained an unusual oak branch, 13 cm in length with 4-mm-thick bark, with five limb nodes that extend in different directions and range from 3 to 4 cm in width.

Thin Section Analysis

Selected samples were coated with Epo-Tek 301 resin prior to cutting to prevent splintering. The wood was then cut at 90° angles (cross section, radial, and tangential) into billets from which the thin sections were prepared. To achieve maximum cell definition, the thin sections were polished to 35 to 45 μm in thickness. No cover slips were applied to the slides. With this technique and the remarkably high degree of preservation in the selected wood specimens, minor wood structures, e.g. circular-bordered pits on tracheid cell walls, could be distinguished and used for identification (Fig. 4A).

Based on thin section analysis, the fossil conifers have been identified as Douglas Fir (*Pseudotsuga menziesii*), Incense Cedar (*Calocedrus decurrens*), and Ponderosa Pine (*Pinus ponderosa*). The dicotyledonous taxa include the families Fagaceae (evergreen and deciduous oaks), Rosaceae (mountain mahogany and hawthorn), and Rhamnaceae (mountain lilac or buck brush).

The representative fossil woods selected for study are listed in Table 1. These include three dicots and two conifers that had cellular structures distinctive enough to be described (S. Carlquist pers. comm. 1996). Thin sections of a pine limb, *Pinus ponderosa* (RMW 5), contain resin canals, uniseriate rays, and uniseriate circular-bordered pits with tracheids that are squarish in outline (Fig. 4B). Conejo conifer RMW 12, possibly an Incense Cedar (*Calocedrus decurrens*) or a Douglas Fir (*Pseudotsuga menziesii*), has more rounded tracheids, as seen in thin section, uniseriate rays, resin canals, and circular-bordered pits. Conifers lack a diversity of water-conducting cells and the homogeneity of their cells produces discrete annual growth rings. Cross-section cuts of this fossil wood show annual rings as the contacts between the small cells of late wood and the large cells of early wood (Fig. 4C).

The more complex cellular organization of the dicot wood shows distinct uniseriate and multiseriate (aggregate) rays, diffuse and aggregate axial parenchyma with mostly solitary vessels, and fiber tracheids (Fig. 4D). Thin sections of an oak branch (RMW 2) have clearly defined tracheids and fiber tracheids, large vessels, and aggregate rays. The diversity of cellular organization in the oak thin sections suggests more than one species.

Other dicots collected from the Conejo tuff breccia include a rosaceous wood specimen (RMW 4) that resembles, but does not belong to, the genus *Heteromeles* or *Adenostoma*. Thin sections of this unidentified dicot show diffuse axial parenchyma, simple perforation plates, tracheids, possible fibers, short vertical uniser-

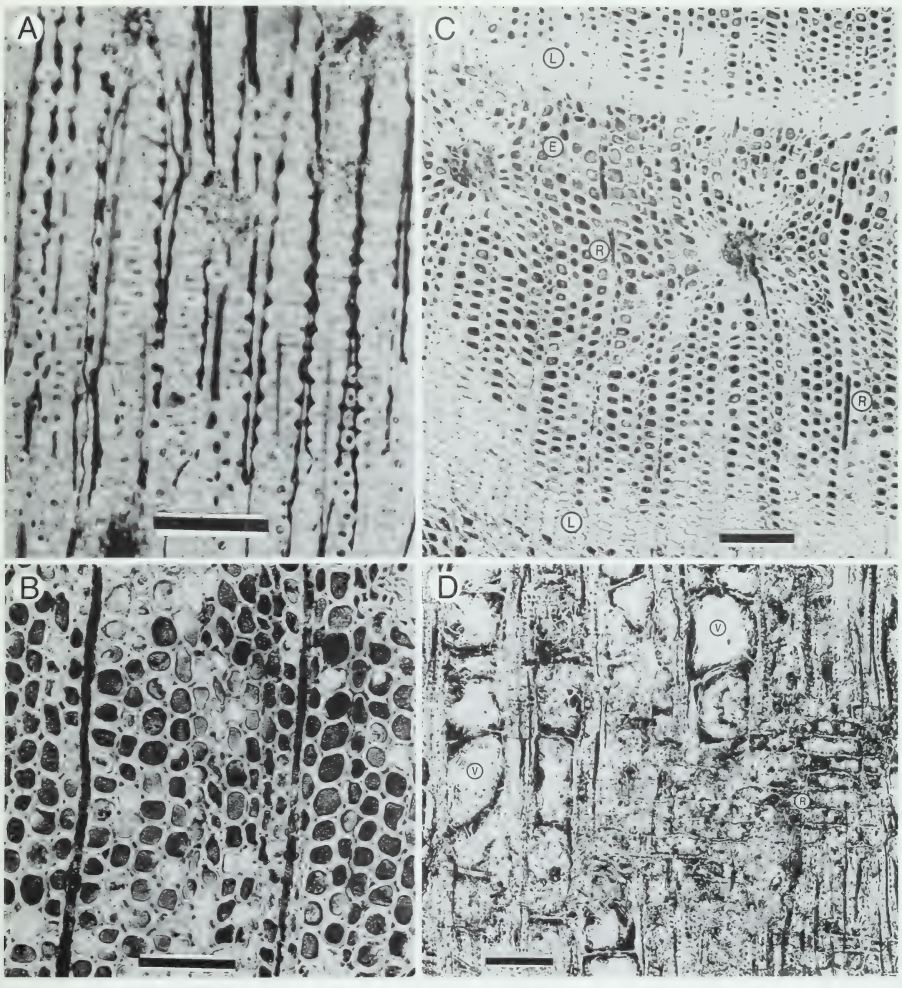

Fig. 4. Photomicrographs of fossil wood from the Conejo Volcanics. A. Ponderosa pine (*Pinus ponderosa*); specimen RMW 5C, radial section. Note circular-bordered pits on tracheid cell walls. Bar represents 85 μm. B. Ponderosa pine (*Pinus ponderosa*); specimen RMW 5A, cross section. Note the well defined, squarish tracheids with thin secondary walls. Two uniseriate rays extend vertically across the image. Bar represents 55 μm. C. Conifer (possibly *Pseudotsuga* or *Calocedrus*); specimen RMW 12 A, cross section. Two resin canals occur among the tracheids of early growth wood (E). Smaller tracheids represent late wood (L). (R) represents a ray. Bar represents 135 μm. D. Oak (*Quercus* sp.); specimen RMW 3C. Radial section shows xylem ray (R) and vessels (V) of axial system. Bar represents 90 μm.

iate rays, and multiseriate rays. The vessels are mostly solitary and growth rings were not observed. Specimen RMW 11 is identified as belonging to the family Rhamnaceae, possibly the genus *Rhamnus* or *Ceanothus*. Its thin sections show unusually narrow multiseriate rays with wings, uniseriate rays, vessels, and tracheids.

Karowe and Jefferson (1987, p. 198) report that fossil woods, associated with tuffs from numerous localities and ages, can undergo silica replications of detailed cellular structures as small as bordered pits on tracheid walls. They noted that

Table 1. Samples selected for thin section analyses.

Slide #	Taxon	View	Slide #	Taxon	View
RMW 1	?Dicot	cross section	CS 971	*Quercus* sp.	cross section
RMW 2	*Quercus* sp.	tangential	RMW 7	*Quercus* sp.	cross section
RMW 3A	*Quercus* cf. *Q. agrifolia*	cross section	RMW 8	?Conifer	cross section
RMW 3B	*Quercus* cf. *Q. agrifolia*	radial	RMW 11A	*Rhamnus* or *Ceanothus*	oblique
RMW 3C	*Quercus* cf. *Q. agrifolia*	tangential	RMW 11B	*Rhamnus* or *Ceanothus*	tangential
RMW 4A	Rosaceous	tangential	RMW 11C	*Rhamnus* or *Ceanothus*	radial
RMW 4B	Rosaceous	radial	RMW 12A	*Pseudotsuga* or *Calocedrus*	cross section
RMW 4C	Rosaceous	cross section	RMW 12B	*Pseudotsuga* or *Calocedrus*	radial
RMW 5A	*Pinus ponderosa*	cross section	RMW 12C	*Pseudotsuga* or *Calocedrus*	tangential
RMW 5B	*Pinus ponderosa*	tangential	DMW 615	*Pinus* sp.	longitudinal
RMW 5C	*Pinus ponderosa*	radial			

". . . lahars provide conditions which are conducive to the excellent preservation of wood: burial is generally rapid and complete, leading to the isolation of organic matter within an anaerobic environment for thousands of years" (Karowe and Jefferson 1987, p.203). The exceptional quality of preservation seen in the Conejo wood thin sections appears typical for flora preserved in lahars.

Discussion

Deposits of fossil wood from eastern Los Angeles Basin formations have been observed by the senior author in the middle to upper Miocene Monterey and Capistrano Formations of the San Joaquin Hills and the foothills of the Santa Ana Mountains, and in the upper Miocene Puente Formation in the Puente Hills and San Jose Hills. Remains of wood and leaves collected from these formations and the Modelo Formation have been studied extensively by Axelrod (1956). He noted that they belong to a subtropical south coastal province and represent a distinctive assemblage that he termed the Madro-Tertiary Geoflora. Included in this flora are willows (*Salix*), buck brush (*Ceanothus*), avocado (*Persea*), palms (*Sabal*), sycamore (*Platanus*), live oak (*Quercus*), cottonwood (*Populus*), mountain mahogany (*Cercocarpus*), juniper (*Juniperus*), and magnolia (*Magnolia*). This assemblage from the Miocene Los Angeles basin region appears ". . . to have survived in mild coastal valleys adjacent to the coast . . ."; similar flora live today ". . . in tropical and subtropical regions extending from Mexico southward" (Axelrod 1956, p. 262). In attempting to compare the Conejo wood assemblage with Axelrod's Madro-Tertiary Geoflora, it should be noted that fossil Miocene trees (sycamore, palm, and avocado), common in other Los Angeles Basin formations, are notably absent.

The subtropical paleoenvironment that characterized southern California in the middle Miocene has become more temperate as temperatures have declined. It is estimated that present-day oaks and conifers live ~600 m lower in elevation than during the warm middle Miocene (J. R. Haller pers. comm. 1997). On the western slopes of the central Sierra Nevada, Ponderosa Pine and Incense Cedar, species represented in the Conejo geoflora, live today from ~700 to 1,500 m elevation (Hughes and Dunning 1949). This implies that the 13.5-Ma Conejo geoflora lived at elevations between 1,300 and 2,100 m.

Axelrod's (1956) Arcto-Tertiary Geoflora from cooler paleoclimates includes maples (*Acer*), mountain lilac or buck brush (*Ceanothus*), Oregon grape (*Mahonia*), pines (*Pinus*), alder (*Alnus*), aspens and cottonwoods (*Populus*), ash (*Fraxinus*), willows (*Salix*), redwood (*Sequoiadendron*), Douglas Fir (*Pseudotsuga*), spruce (*Picea*), and sumac (*Rhus*). Apparently missing are oaks, which are common in the Conejo flora, and this absence of oaks makes it impossible to assign the Conejo geoflora to the Arcto-Tertiary Geoflora.

Unlike the Tertiary geofloras described by Raven and Axelrod (1995), the Conejo flora appears closely related to oak and pine forests, found today in the west-central Sierra Nevada Mountains and northern California. These transitional forests contain Valley Oak, Live Oak, Coast Live Oak, Pacific Madrone, California Laurel, Incense Cedar, Douglas Fir, and Ponderosa Pine (Kricher and Morrison 1993, p. 328). The life zone of this conifer/hardwood forest belongs to the Low Montane Zone of 730 to 1,850 m elevation with an annual precipitation of 62.5 cm (Kricher and Morrison 1993, p. 282–287).

The geoflora preserved in the Conejo Volcanics tuff appears to represent a low montane forest that grew on an active volcanic highland ~13.5 Ma when coastal temperatures were subtropical. The gradual decline in temperatures since the medial Miocene and the composition of the Conejo geoflora suggest that the elevation of this volcano was greater than 1,300 m. It is plausible that a lahar carried conifers from a higher elevation down slope where the pines, firs, and cedars were buried with oaks and other dicots. However, the absence of genera common in other Los Angeles Basin Miocene deposits (e.g. palms, sycamores, and avocados) suggests that the Conejo fossil wood may represent a low montane geoflora previously undescribed from the geologic record of the Los Angeles Basin region.

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The fossil wood specimens have been deposited at the Santa Barbara Botanic Garden, the Geology Department of Pomona College, the Santa Monica National Recreation Area Visitor's Center, and the City of Westlake Village, California.

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First Record of *Isocyamus kogiae* Sedlak-Weinstein, 1992 (Crustacea, Amphipoda, Cyamidae) from the Eastern Pacific, with Comments on Morphological Characters, a Key to the Genera of the Cyamidae, and a Checklist of Cyamids and their Hosts

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Abstract.—The cyamid amphipod species *Isocyamus kogiae* Sedlak-Weinstein, 1992, is reported for the first time from southern California, extending the known range of the species from Moreton Island, Queensland, Australia, to the northeastern Pacific. Additional descriptive notes are provided based on a single adult male taken from a pygmy sperm whale, *Kogia breviceps* (de Blainville, 1838), stranded near San Diego, California. Morphological differences between this specimen and the description of the type series are discussed. A revised key to the six currently recognized genera of the family Cyamidae is provided, as well as a checklist of all described species of the family, their cetacean hosts, and the ranges of those hosts.

The amphipod crustacean family Cyamidae Rafinesque, 1815, is a relatively species-poor taxon, all members of which are ectoparasites on cetaceans (Laubitz 1982). Subsequent to Leung's (1967) review, where only 16 species in 5 genera were treated, there have been only one new genus (*Scutocyamus* Lincoln and Hurley, 1974) and relatively few other species described (e.g. Leung 1970b, Lincoln and Hurley 1974, 1980, 1981, Berzin and Vlasova 1982, Waller 1989, Sedlak-Weinstein 1992a, b). Currently, the family contains six genera and approximately 27 species (see Table 1).

Prior to 1992, there were no descriptions of cyamids associated with pygmy sperm whales, *Kogia breviceps* (de Blainville, 1838). Although Caldwell et al. (1971) reported a cyamid attached to one of seven pygmy sperm whales from the western Atlantic examined by them, they did not describe the cyamid, referring to it only as "Cyamidae, form D, genus and species undetermined" (Caldwell et al. 1971: 4). All specimens of cetacean parasites mentioned in that paper as being in the personal collection of Stephen Zam were subsequently lost in an office move (personal communication, Stephen Zam, 29 June 1993).

In 1992, a new species of cyamid was described by Sedlak-Weinstein (1992a) from a pygmy sperm whale that stranded on Moreton Island, Queensland, Australia, marking the first record of cyamids taken from the genus *Kogia* (with the exception of the western Atlantic record above). Sedlak-Weinstein's species proved to belong to the genus *Isocyamus,* but differed sufficiently from *I. delphinii,* the sole previous member of the genus, to necessitate the erection of a second species of the genus, *Isocyamus kogiae.* A third species of *Isocyamus, I.*

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Table 1. Known cyamid amphipods of the world and their cetacean hosts and distributions, compiled mostly from Leung (1965, 1967), Gruner (1975), Berzin and Vlasova (1982), and Sedlak-Weinstein (1991, 1992a, b). Additional earlier specific names now considered junior synonyms are listed in Gruner (1975). Selected host references are not meant to be exhaustive; numerous additional accounts exist in the cetacean and crustacean literature. Taxonomy of the host species has been updated based on Mead and Brownell (1993).

Family Cyamidae Rafinesque, 1815	Selected Host References
Genus *Cyamus* Latreille, 1796	
Cyamus antarcticensis Vlasova, 1982, in Berzin and Vlasova	
Orcinus orca (Linnaeus, 1758)	
(killer whale; worldwide)	Berzin and Vlasova, 1982
Cyamus bahamondei Buzeta, 1963	
Physeter catodon Linnaeus, 1758	Leung, 1965; Gruner, 1975
(sperm whale; non-polar worldwide)	Berzin & Vlasova, 1982
Cyamus balaenopterae Barnard, 1931	
Balaenoptera musculus (Linnaeus, 1758)	
(blue whale; worldwide)	Gruner, 1975
Balaenoptera physalus (Linnaeus, 1758)	
(fin whale; worldwide)	Leung, 1965; Gruner, 1975
Balaenoptera acutorostrata Lacépède, 1804	
(minke whale; worldwide)	Gruner, 1975
Cyamus boopis Lutken, 1870	
Megaptera novaeangliae (Borowski, 1781)	
(humpback whale; worldwide)	Leung, 1965; Gruner, 1975
Physeter catodon Linnaeus, 1758	Gruner, 1975
(sperm whale; non-polar worldwide)	Berzin & Vlasova, 1982
unidentified New Zealand whale	Sedlak-Weinstein, 1991
unidentified south Australian whale	Sedlak-Weinstein, 1991
Cyamus catodontis Margolis, 1954	
Physeter catodon Linnaeus, 1758	Leung, 1965; Gruner, 1975
(sperm whale; non-polar worldwide)	Berzin & Vlasova, 1982; Fransen and Smeenk, 1991
Cyamus ceti (Linnaeus, 1758)	
Balaena mysticetus Linnaeus, 1758	Gruner, 1975
(bowhead whale; Arctic)	Leung, 1965, 1976
Eschrichtius robustus Lilljeborg, 1861	Lueng, 1965
(gray whale; North Pacific; also North Atlantic in historic times)	Gruner, 1975
Cyamus erraticus Roussel de Vauzeme, 1834	
Eubalaena australis (Desmoulins, 1822)	
(southern right whale; southern hemisphere)	Leung, 1965; Gruner, 1975
Eubalaena glacialis (Muller, 1776)	
(northern right whale; northern hemisphere)	Leung, 1965; Gruner, 1975
Megaptera novaeangliae (Borowski, 1781)	
(humpback whale; worldwide)	Gruner, 1975
Cyamus gracilis Roussel de Vauzeme, 1834	
Eubalaena australis (Desmoulins, 1822)	
(southern right whale; southern hemisphere)	Leung, 1965; Gruner, 1975
Eubalaena glacialis (Muller, 1776)	
(northern right whale; northern hemisphere)	Leung, 1965; Gruner, 1975

Table 1. Continued.

Family Cyamidae Rafinesque, 1815	Selected Host References
Cyamus kessleri A. Brandt, 1873	
Eschrichtius robustus (Lilljeborg, 1861) (gray whale; North Pacific; also North Atlantic in historic times)	Hurley and Mohr, 1957 Leung, 1965; Gruner, 1975
Cyamus monodontis Lutken, 1870	
Monodon monoceros Linnaeus, 1758 (narwhal; Arctic)	Leung, 1965; Gruner, 1975
Delphinapterus leucas (Pallas, 1776) (beluga; Arctic)	Gruner, 1975
Cyamus nodosus Lutken, 1861	
Monodon monoceros Linnaeus, 1758 (narwhal; Arctic)	Leung, 1965; Gruner, 1975
Delphinapterus leucas (Pallas, 1776) (beluga; Arctic)	Gruner, 1975
Cyamus orcini Leung, 1970b	
Orcinus orca (Linnaeus, 1758) (killer whale; worldwide)	Leung, 1970b; Gruner, 1975
Cyamus orubraedon Waller, 1989	
Berardius bairdii Stejneger, 1883 (Baird's beaked whale; North Pacific)	Waller 1989 Gruner, 1975; Leung, 1965, 1970a, b
Cyamus ovalis Roussel de Vauzeme, 1834	
Eubalaena australis (Desmoulins, 1822) (southern right whale; southern hemisphere)	Leung, 1965; Gruner, 1975
Eubalaena glacialis (Muller, 1776) (northern right whale; northern hemisphere)	Leung, 1965; Gruner, 1975
Physeter catodon Linnaeus, 1758 (sperm whale; non-polar worldwide)	Leung, 1965; Gruner, 1975 Berzin & Vlasova, 1982
Cyamus rhytinae (J. F. Brandt, 1846) {dubious species, supposedly found on Steller's sea cow; See Gruner, 1975: 88}	
Cyamus scammoni Dall, 1872	
Eschrichtius robustus Lilljeborg, 1861 (gray whale, North Pacific; also North Atlantic in historic times)	Gruner, 1975 Leung, 1965, 1976
Genus *Isocyamus* Gervais & Van Beneden, 1859	
Isocyamus delphinii Guerin-Meneville, 1837	
Globicephala melas (Traill, 1809) (long-finned pilot whale; temperature waters)	Sedlak-Weinstein, 1991 Gruner, 1975 Berzin and Vlasova, 1982 Sedlak-Weinstein, 1992a Leung, 1965 Raga et al., 1983
Globicephala macrorhynchus Gray, 1846 (short-finned pilot whale; temperate and tropical, worldwide)	Hiro, 1938 Sedlak-Weinstein, 1992a
Pseudorca crassidens (Owen, 1846) (false killer whale; temperate and tropical, worldwide)	Sedlak-Weinstein, 1991 Gruner, 1975 Sedlak-Weinstein, 1992a Bowman, 1955

Table 1. Continued.

Family Cyamidae Rafinesque, 1815	Selected Host References
Steno bredanensis (Lesson, 1828)	Gruner, 1975
(rough toothed dolphin; temperate and tropical worldwide)	Lincoln and Hurley, 1974
	Sedlak-Weinstein, 1992b
Delphinus delphis[a] Linnaeus, 1758	Gruner, 1975
(common dolphin; temperate and	Berzin and Vlasova, 1982
tropical, worldwide)	Sedlak-Weinstein, 1992a
Grampus griseus (G. Cuvier, 1812)	Gruner, 1975
(Risso's dolphin; temperate and tropical,	Berzin and Vlasova, 1982
worldwide)	Sedlak-Weinstein, 1992a
Phocoena phocoena (Linnaeus, 1758)	Gruner, 1975
(harbor porpoise; northern hemisphere,	Stock, 1977
temperate)	Berzin and Vlasova, 1982
	Sedlak-Weinstein, 1992a
	Fransen and Smeenk, 1991
Tursiops truncatus (Montagu, 1821)	Balbuena and Raga, 1991
(bottlenose dolphin; tropical and temperate)	Sedlak-Weinstein, 1992a
Lagenorhyncus albirostris Gray, 1846	Stock, 1977
(white-beaked dolphin; temperate North	Sedlak-Weinstein, 1992a
Atlantic)	Fransen and Smeenk, 1991
Mesoplodon europeaus	Balbuena and Raga, 1991
(Antillean beaked whale; North Atlantic)	Sedlak-Weinstein, 1992a
Orcinus orca	Best, 1969
(killer whale; worldwide)	Sedlak-Weinstein, 1992a
Isocyamus deltobranchium Sedlak-Weinstein, 1992b	
Globicephala macrorhynchus Gray, 1946	
(short-finned pilot whale; temperate and	
tropical waters)	Sedlak-Weinstein, 1992b
Globicephala melas (Triall, 1809)	
(long-finned pilot whale; temperate)	Sedlak-Weinstein, 1992b
Isocyamus kogiae Sedlak-Weinstein, 1992a	
Kogia breviceps (de Blainville, 1838)	Sedlak-Weinstein, 1992a; This
(pygmy sperm whale; tropical to warm	study
temperate)	
Genus *Neocyamus* Margolis, 1955	
Neocyamis physeteris (Pouchet, 1888)	
Physeter catodon Linnaeus, 1758	Leung, 1965; Gruner, 1975
(sperm whale; non-polar worldwide)	Berzin and Vlasova, 1982
Phocoenoides dalli (True, 1885)	Gruner, 1975
(Dall's porpoise; North Pacific, temperate)	Berzin and Vlasova, 1982
Genus *Platycyamus* Lutken, 1870	
Platycyamus thompsoni (Gosse, 1855)	
Mesoplodon grayi Von Harst, 1876	
(Gray's beaked whale; southern hemisphere)	Sedlak-Weinstein, 1991
Hyperoodon planifrons Flower, 1882	
(southern bottlenose whale; southern hemisphere)	Berzin and Vlasova,1982
Hyperoodon ampullatus (Forster, 1770)	Gruner, 1975
(northern bottlenose whale;	Berzin and Vlasova, 1982
northern hemisphere)	Fransen and Smeenk, 1991

Table 1. Continued.

Family Cyamidae Rafinesque, 1815	Selected Host References
Platycyamus flaviscutatus Waller, 1989	
Berardius bairdii Stejneger, 1883	Waller, 1989
(Baird's beaked whale; North Pacific)	Leung, 1967, 1970a; Berzin and Vlasova, 1982
Genus *Scutocyamus* Lincoln and Hurley, 1974	
Scutocyamus parvus Lincoln and Hurley, 1974	
Lagenorhynchus albirostris (Gray, 1846)	Lincoln & Hurley, 1974
(white-beaked dolphin; temperate North Atlantic)	Gruner, 1975
	Fransen and Smeenk, 1991
Scutocyamus antipodensis Lincoln and Hurley, 1980	
Cephalorhynchus hectori (Van Beneden, 1881)	Lincoln & Hurley, 1980;
(Hector's dolphin; New Zealand)	Sedlak-Weinstein, 1991
Genus *Syncyamus* Bowman, 1955	
Syncyamus chelipes (Costa, 1866)	
Delphinus delphis[1] Linnaeus, 1758	
(common dolphin; temperate and tropical waters)	Gruner, 1975
Syncyamus pseudorcae Bowman, 1955	
Pseudorca crassidens (Owen, 1846)	Bowman, 1955
(false killer whale; temperate and tropical waters)	Gruner, 1975
	Sedlak-Weinstein, 1991
Syncyamus aequus Lincoln and Hurley, 1981	
Tursiops truncatus (Montagu, 1821)	
(bottlenose dolphin; tropical and temperate)	Sedlak-Weinstein, 1991
Stenella longirostris[2] (Gray, 1828)	
(Spinner dolphin; tropical)	Sedlak-Weinstein, 1991
Stenella coeruleoalba (Meyen, 1833)	Raga and Raduan, 1982
(striped dolphin; tropical and temperate)	Raga, 1988
Syncyamus sp. Bowman, 1958 (close to *S. pseudorcae* Bowman, 1955)	
Stenella attenuata[3] (Gray, 1846)	Bowman, 1958
(spotted dolphin; pan-tropical)	Gruner, 1975
Syncyamus sp. Leung, 1970 (close to *S. pseudorcae* Bowman, 1955)	
Delphinus delphis[1] Linnaeus, 1758	
(common dolphin; temperate and tropical)	Leung, 1965; Gruner, 1975
Stenella coeruleoalba (Meyen, 1833)	
(striped dolphin; tropical and temperate)	Leung, 1965; Gruner, 1975
Stenella longirostris[2] (Gray, 1828)	
(spinner dolphin; tropical)	Leung, 1965; Gruner, 1975
Tursiops truncatus (Montagu, 1821)	
(bottlenose dolphin; tropical and temperate)	Leung, 1965; Gruner, 1975

Gruner (1975: 93) lists as "doubtful species" the following:
Cyamus latreilleii A. Smith, 1831
Cyamus leachii A. Smith, 1831

[1] *Delphinus delphis* has been divided into *D. delphis* and *D. capensis* Gray, 1828; see Heyning and Perrin (1994).

[2] *Stenella longirostris* has been divided into *S. longirostris* and *S. clymene* (Gray, 1846); see Perrin et al. (1981).

[3] *Stenella attenuata* has been divided into *S. attenuata* and *S. frontalis* (G. Cuvier, 1829); see Perrin et al. (1987).

deltobranchium, has now been described from Japanese and Australian pilot whales (see Sedlak-Weinstein 1992b).

On 21 May 1993, a pygmy sperm whale stranded alive in San Diego County, California. The whale was taken to Sea World™ in San Diego where it died the same day. The whale was frozen intact and then transported to the Natural History Museum of Los Angeles County (LACM). The cetacean was subsequently found to have a single attached cyamid amphipod, which we have attributed to *Isocyamus kogiae* Sedlak-Weinstein, 1992a. However, sufficient morphological differences exist between this specimen and the original description of the type of *I. kogiae,* and between other members of the genus *Isocyamus,* that we felt it appropriate to describe and discuss our specimen below. Additionally, we provide a more detailed diagnosis of the genus *Isocyamus,* a key to the six known cyamid genera, and an updated checklist of species of the Cyamidae and their hosts.

Materials and Methods

The stranded pygmy sperm whale was a 3.00 m male, the skeleton and selected tissues of which are catalogued in the Natural History Museum of Los Angeles County's collection of mammals as LACM 88938. The cyamid was found on the dorsolateral flank of the host, approximately two-thirds the body length posterior to the head. The dactyli of the pereiopods were firmly embedded in the epidermis of the whale. The whale's body at the site of the cyamid was free of wounds. However, prior to the discovery of the cyamid, the whale was transported by truck to Sea World, subsequently died, and was frozen. Therefore, the relative position of the cyamid upon the whale's body may be a post-stranding artifact. Illustrations were made with a Wild M5APO stereo microscope and a Nikon Labophot™, both equipped with a drawing tube. The cyamid specimen is catalogued as LACM 93-34.1 in the Crustacea collections of the Natural History Museum of Los Angeles County, a collection that contains the most extensive holdings of cyamids in the world (see Leung 1965).

Results

Isocyamus Gervais and van Beneden, 1859

Emended diagnosis.—Body thin and elongate, not ovate. Pigment lacking, imparting whitish color. Head widest at base, tapering slightly anteriorly. Antenna 1 long, exceeding length of either first or second pereiopod, composed of 4 articles. Antenna 2 with 3 articles (possibly 4 articles; distinction between distal most articles difficult to discern). Maxillipeds extremely reduced, flap-like. Maxillipedal palps lacking. First pereon fused with head. All subsequent pereonal somites fused dorsally at midline. Pereiopod (gnathopod) 1 slightly shorter and much thinner than pereiopod 2, composed of 6 articles. Dactylus of pereiopod 1 with comb row along cutting border; comb row either single (*I. delphinii*) or double, extending from tip proximally to at least midway point along ventral border. Dactylus with or without distinct unguis. Pereiopod (gnathopod) 2 robust, composed of 4 articles; dactylus smooth. Somite 2 with epaulet-like infoldings of cuticle along anterodorsal border. Somites 3 and 4 bearing single (unpaired), elongate and tubular primary gill and well-developed accessory gill equal in size to (*I. delphinii*) or smaller than primary gills. Sternal area just posterior to and lateral to each primary gill bearing laterally directed acute process. Oostegites rounded,

not triangular or wedge-shaped. Pereiopods 5, 6, and 7 similar, each terminating in smooth, sickle-shaped dactylus (as per family), each lacking ventral spines on any article, each with dorsal ridge-like process extending proximally on basis; this process most obvious on pereiopod 5. Adjacent sternal region with or without (*I. kogiae*) ventrally-directed spines.

Species: *Isocyamus delphinii* (Guerin-Meneville, 1836); *Isocyamus kogiae* Sedlak-Weinstein, 1992a; *Isocyamus deltobranchium* Sedlak-Weinstein, 1992b (see Table 1 for host species).

Comparison of *Isocyamus kogiae* specimens from California and Australia

Our specimen (Figs. 1, 2), a mature male, agrees with Sedlak-Weinstein's (1992a) original description of *I. kogiae* in most major morphological features, such as the relative size of the gnathopods, size and shape of the head, fusion of all pereonites dorsally, presence of epaulet-like processes on the second pereon, size and shape of primary and accessory gills, absence of sternal spines adjacent to pereiopods 5–7, and presence of an acute tooth on the propodus of gnathopod 2. Size of the specimens is also in agreement; our specimen (measured following Sedlak-Weinstein 1992a, and with corresponding measurements of the holotype from Australia given in brackets) measured: total length 4.7 mm [4.75]; width of body 1.4 mm [1.5]; length of primary gill 1.0 mm [1.0]; length of propodus of first gnathopod 0.7 mm [0.5]. Because our sole specimen is a mature male, we can not offer comparisons with Sedlak-Weinstein's allotype.

Our specimen differs from the Australian specimens in having a more strongly curved dactylus on pereiopods 5–7, a slightly different shape to the propodal distal expansion of the second gnathopod (which in the type specimens also bears a second, more proximal, blunt expansion not seen on our specimen), and a slightly different shape to the dactylus and propodus of gnathopod 1. In our specimen, the rounded ventral border of the propodus of gnathopod 1 bears a row of minute spines or teeth, corresponding to what is found on the dactylus; these spines were not mentioned or illustrated by Sedlak-Weinstein (1992a), but may have been overlooked. Another difference is that the accessory gills of our specimen are distally rounded (Figs. 1a, c), whereas they appear more tapered in Sedlak-Weinstein's illustration (1992a: fig. 2), but are well rounded in the paratypes (T. Haney, pers. com.).

Because we had only one specimen, we did not remove mouthparts for separate illustration or subject the specimen to SEM; mouthparts shown here (Fig. 2c) were illustrated in situ, so details are more difficult to see and illustrate. Still, some differences in the mouthparts between our specimen and the Australian series are evident. The most obvious is that in our specimen the second maxillae are fused basally, whereas in Sedlak-Weinstein's illustration (1992a: 4, fig. 11) these are shown as being separate basally. Additionally, her figure of the maxillipeds shows two distinct processes, each with three terminal setae (4–5 in text), whereas we detected only a small, crescent-shaped flap of cuticle, and did not see any setation.

Finally, our specimen differs from the Australian specimens of *I. kogiae,* and indeed from all other described cyamids, in having the last pair of legs displaced anteriorly so that they fall anterior to the penultimate pair; this is unique in the family. Although perhaps appearing as an artifact, the amount of dislocation of

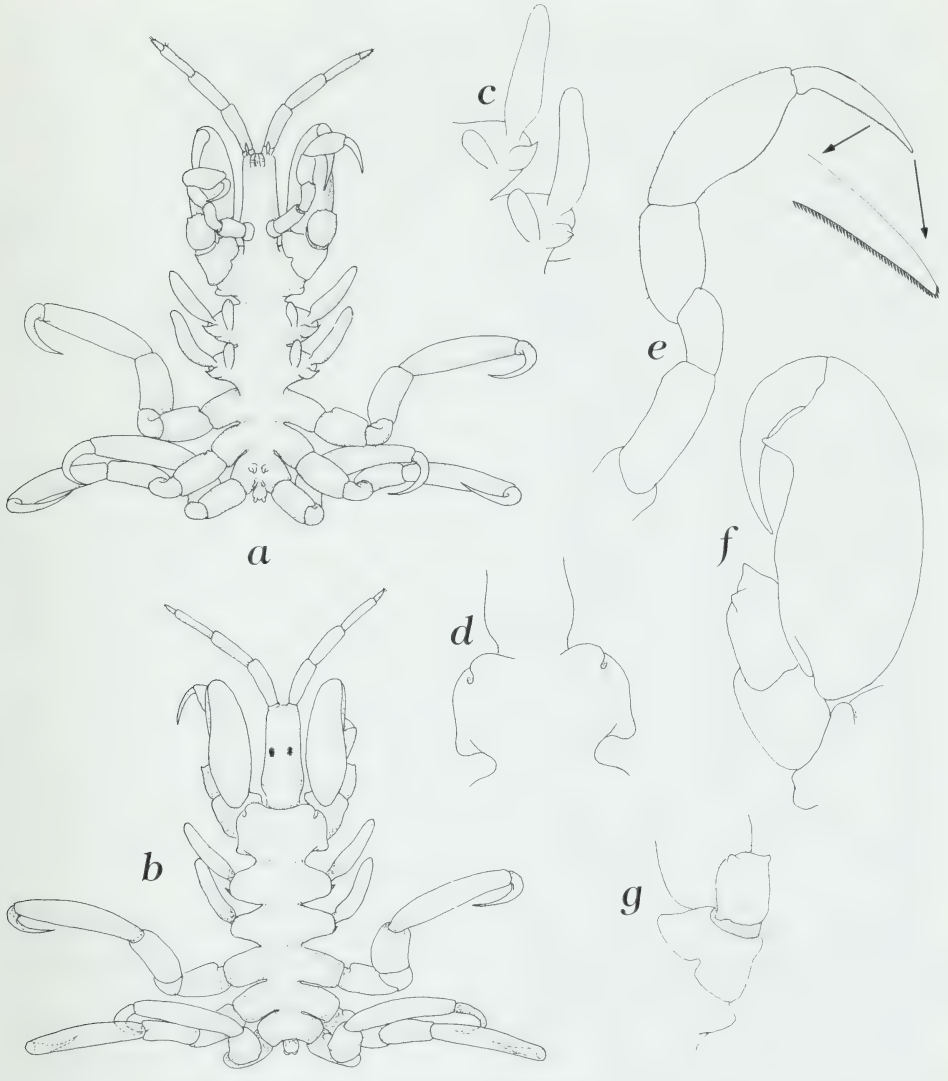

Fig. 1. *Isocyamus kogiae* Sedlak-Weinstein, 1992a, from pygmy sperm whale (*Kogia breviceps*) stranded in San Diego, California. a, Entire animal, ventral view. b, same, dorsal view. c, Primary and accessory gills and ventrally projecting processes of somites 3 and 4. Note ventrolateral process of somite 3 directed more laterally than that of somite 4. d, Dorsal view of somite 2. Note epaulet-like infoldings of cuticle at anterodorsal margins. e, First gnathopod with tip of dactylus enlarged at lower right showing comb row. f, Second gnathopod. g, Ventral view of proximal two articles of gnathopod 2 and part of propodus.

the legs that would be necessary to return the posterior most leg to its "usual" position is substantial, and would involve bilaterally pulling the back legs a considerable distance upward in order for the long claw-like dactylus to clear the other legs. This very unusual feature is immediately diagnostic, but could be overlooked in a disarticulated or damaged specimen, or even one that has been manipulated to the point that the pereiopods are in the "normal" arrangement.

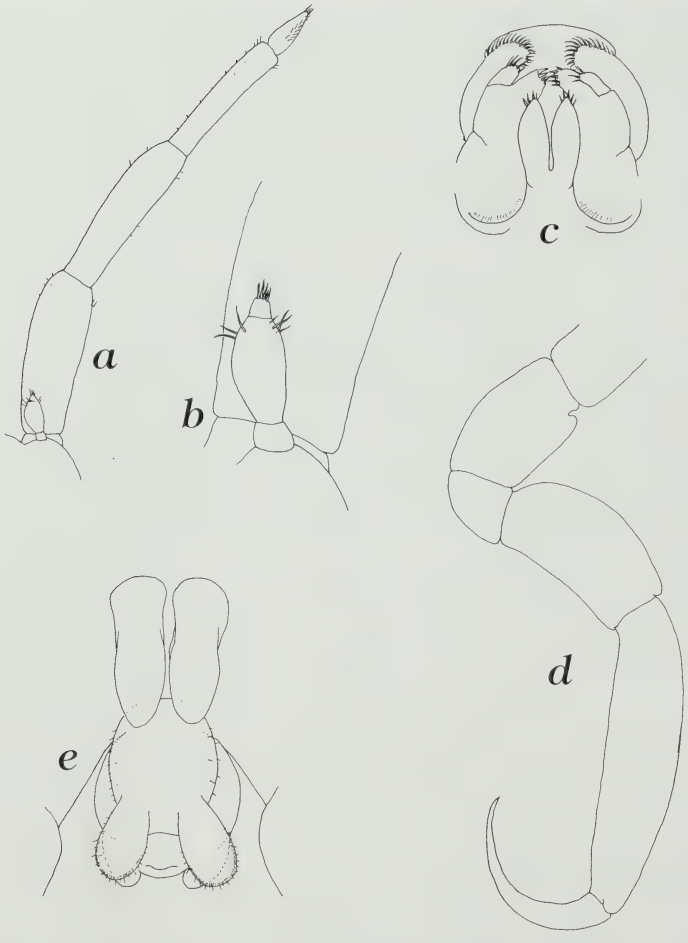

Fig. 2. *Isocyamus kogiae* Sedlak-Weinstein, 1992a, from pygmy sperm whale (*Kogia breviceps*) stranded in San Diego, California. a, First and second antenna. b, Close up of second antenna showing indistinct suture at base of distal most article. c, Entire mouthfield, ventral view. d, Pereiopod 7. e, Abdominal region and male genitalia, ventral view.

This condition does not occur in the collection of 9 females and 5 males of *I. kogiae* from Australia.

Based on known variability of some cyamid features (e.g. Raga 1988), and because of the similarities of the southern California specimen to Sedlak-Weinstein's (1992a) description of *Isocyamus kogiae* from the same host (*Kogia breviceps*) off Australia, we do not believe the above differences warrant erection of another species of the genus.

Currently Recognized Genera of the Cyamidae

As currently recognized, the family Cyamidae contains only the genera *Cyamus* Latreille, 1796; *Isocyamus* Gervais and van Beneden, 1859; *Platycyamus* Lutken, 1870; *Syncyamus* Bowman, 1955; *Neocyamus* Margolis, 1955; and *Scutocyamus* Lincoln and Hurley, 1974. Most species in the family are members of the genus *Cyamus,* currently containing 16 nominal species (Table 1; see also Gruner 1975,

Berzin and Vlasova 1982). Species within the genus *Cyamus* have a second maxilla that bears an outer lobe and possess a maxillipedal palp (variously developed, and absent in early stages of some species, and lacking in all stages of *Cyamus nodosus* [T. Haney, personal communication]), features lacking in members of the other genera (Bowman 1955, Leung 1967, Lincoln and Hurley 1974).

Other genera of the Cyamidae contain few species; *Neocyamus* is monotypic, and the genera *Platycyamus, Syncyamus,* and *Scutocyamus* have but two species each. *Isocyamus* was erected by Gervais and van Beneden (1859), and later described in more detail by Barnard (1932), to accommodate *I. delphinii* (often incorrectly spelled *delphini*), originally described (as *Cyamus*) by Guerin-Meneville (1836) from the common dolphin, *Delphinus delphis. Isocyamus dephinii* has since been reported from a number of small odontocetes (listed in table 1 of Sedlak-Weinstein 1992a; see also Table 1).

Leung (1967), in his key to the genera, employed as a character separating *Isocyamus* from *Cyamus* the fact that *Isocyamus* bears laterally directed spines at the bases of the gills. Unfortunately, these laterally directed spines are not unique to *Isocyamus*; Leung himself illustrated these quite clearly for *Cyamus kessleri* (see Leung 1967: fig. 4a), and they are also evident in the most recently described member of that genus, *Cyamus antarcticensis* Berzin and Vlasova (1982: 152, figs. 1A, 2G), as well as in *Isocyamus.* Thus, Leung's (1967) key to cyamid genera was seriously flawed even at the time of publication, and included only 5 genera and 16 species. There exists today no valid key for the separation and identification of cyamid genera. An additional problem is that some morphological characters employed in cyamid taxonomy were poorly or incompletely described in the original species accounts. Mouthparts, details of which may prove to be the best or the only indicators of phylogenetic affinity, remain undescribed—or are incorrectly described—for several genera and most species. For example, although Bowman (1955) stated that *Isocyamus* has a 2-segmented palp on the first maxilla, this is incorrect as all three species, *I. delphinii, I. deltobranchium,* and *I. kogiae*, have a 1-segmented palp on this appendage (Sedlak-Weinstein 1992a, b). Details of the male abdomen and reproductive structures are sketchy at best in the literature, and are not illustrated for most species of *Cyamus*; even the terminology and homologies of these structures are unclear. Clearly, although the Cyamidae contains relatively few genera and species, there remains a considerable amount of taxonomic confusion, and a systematic revision of the group, including redescriptions of all species, is badly needed. To facilitate more accurate identification of cyamids, at least to the level of genus, we have constructed a revised key that is admittedly artificial, employing what appear to us (from the literature and from examination of select taxa in the LACM Crustacea Collection) to be fairly conservative characters.

Revised Key to the Genera of the Cyamidae

1. Gills fasciculate (highly branched, appearing as bundles). Males lacking accessory gills ..... *Neocyamus*
– Gills not fasciculate. Males with or without accessory gills 2
2. Gnathopods 1 and 2 approximately equal in size. Pereon 1 extending laterally beyond lateral margins of head, clearly separated from head by distinct indentation ..... *Platycyamus*

– Gnathopod 1 distinctly smaller (shorter and thinner) than gnathopod 2. Pereon 1 not extending laterally beyond lateral margins of head, or if so then fused to head, not separated from it by distinct indentation 3
3. Pereon 3 and 4 greatly reduced in male, fused dorsally in both sexes. Gnathopod 2 composed of 3 articles. Pereon 6–7 fused. Males without accessory gills ..... *Scutocyamus*
– Pereon 3 and 4 not reduced or reduced in male, fused or unfused dorsally in both sexes. Gnathopod 2 composed of 5 articles. Pereon 6–7 fused or unfused. Males with accessory gills 4
4. Antenna 2 with 4 articles. Maxilliped occasionally with palp in adult. Pereon 2 without infoldings of cuticle along anterodorsal region ... *Cyamus*
– Antenna 2 composed of 2 or 3 articles. Maxilliped greatly reduced, never with palp in adult. Pereon 2 with epaulet-like cuticular infoldings on anterodorsal region 5
5. Combined head and pereon 1 arising from recessed area along front of pereon 2. Antenna 1 shorter than either gnathopod and shorter than fused head + pereon 1. Pereiopods 5–7 short, heavy. Adults not greater than 3 mm total length ..... *Syncyamus*
– Combined head and pereon 1 not arising from recessed area in pereon 2. Antenna 1 elongate, clearly exceeding length of head + pereon 1. Pereiopods 5–7 elongate, delicate. Adults greater than 4 mm total length (usually 6–9 mm) ..... *Isocyamus*

Discussion

In the first report of any cyamid from a pygmy sperm whale, Caldwell et al. (1971) reported that the undescribed cyamid (now lost) was taken from "infected tissue in [an] unhealed open lesion penetrating the skin into the underlying adipose tissue on the side of the body." The *Kogia breviceps* from which that cyamid was taken was a 3.2 m male (Caldwell and Caldwell 1989: 255) from northeastern Florida in the vicinity of St. Augustine (Caldwell et al. 1971: 4). Similarly, Sedlak-Weinstein's (1992a) pygmy sperm whale cyamids were collected "from among 20 'golf ball-sized' wounds" on the stranded host. These described wounds are characteristic of those inflicted by cookie-cutter sharks. In contrast, the southern California cyamid specimen from *Kogia breviceps* was found firmly attached to healthy tissue just posterior to midlength.

Interestingly, only species of the genus *Cyamus* have been taken from baleen whales (suborder Mysticeti), whereas species of all six genera, including *Cyamus,* have been found on various members of the toothed whales (suborder Odontoceti) (see Leung 1967 and Table 1). Unfortunately, all systematic investigations of cyamids to date have been of a phenetic rather than cladistic nature, precluding for the moment comparisons of cyamid and cetacean phylogenies.

Acknowledgments

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Helminths of the Western Toad, *Bufo boreas* (Bufonidae) from Southern California

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Abstract.—Museum specimens of *Bufo boreas* from southern California were examined for helminths. The helminth fauna consisted of one trematode species, *Haematoloechus kernensis,* one cestode species, *Distoichometra bufonis,* six nematode species, *Aplectana itzocanensis, Cosmocercoides variabilis, Falcaustra inglisi, Oswaldocruzia pipiens, Rhabdias americanus, Physaloptera* sp. (third stage larvae only). Helminths found in *B. boreas* are generalists occurring in other anuran species. *Bufo boreas* represents a new host record for *H. kernensis, A. itzocanensis, F. inglisi,* and *Physaloptera* sp. (larvae).

The western toad, *Bufo boreas* Baird and Girard 1852, occurs from southern Alaska to northern Baja California, from the Pacific Coast to the Rocky Mountains and from sea level to over 3600 m (Stebbins 1985). There are five previous reports of helminths in *B. boreas:* California (Ingles 1936; Walton 1941; Koller and Gaudin 1977), Idaho (Waitz 1961), and Utah (Frandsen and Grundmann 1960). The purpose of this study is to present additional helminth records for *B. boreas* from southern California.

Sixty-nine *B. boreas* from the herpetology collection of the Natural History Museum of Los Angeles County (LACM) were examined: Los Angeles County (N = 30, collected 1958, 1972, mean snout-vent length [SVL] = 73.4 mm ± 14.8 SD, range 37–95 mm, LACM 115185–115208, 144207–144208, 144210–144213); Orange County (N = 3, collected 1972, SVL = 84.7 mm ± 7.2 SD, range 80–93 mm, LACM 144209, 144214–144215); Riverside County (N = 11, collected 1958–1959, 1964, 1966–1967, SVL = 82.0 mm ± 10.1 SD, range 64–102 mm, LACM 11218, 11220–11221, 11223, 87313–87316, 87323, 87325, 87327); San Bernadino County (N = 25, collected 1955, SVL = 67.2 mm ± 9.3 SD, range 47–81 mm, LACM 11297–11300, 11302, 11305–11307, 11309–11315, 11318, 11343–11344, 11351–11352, 11355–11357, 11359, 11362).

Toads had been fixed in 10% formalin and preserved in 70% ethanol. The body cavity was opened by a longitudinal incision from throat to vent and the digestive tract (esophagus, stomach, small and large intestine), lungs and urinary bladder were removed and examined for helminths with a dissecting microscope. The liver and body cavity were also searched for helminths. Helminths were intitially examined using the standard glycerol wet-mount procedure. Nematodes were identified from these wet mounts. Trematodes and cestodes were stained in hematoxylin, dehydrated in increasing concentrations of ethanol, cleared in xylene and mounted in balsam for identification. Terminology is in accordance with Bush et al. (1997).

The helminth fauna of *B. boreas* examined in this study consisted of one species of Trematoda, *Haematoloechus kernensis* Ingles 1932; one species of Cestoda, *Distoichometra bufonis* Dickey 1921; and six species of Nematoda, *Aplectana itzocanensis* Bravo Hollis 1943, *Cosmocercoides variabilis* (Harwood 1930), *Falcaustra inglisi* (Anderson 1964), *Oswaldocruzia pipiens* Walton 1929, *Rhabdias americanus* Baker 1978 and *Physaloptera* sp (third-stage larvae only). Selected helminths were placed in vials of 70% ethanol and deposited in the U.S. National Parasite Collection (USNPC), Beltsville, Maryland as: *Haematoloechus kernensis* (88065); *Distoichometra bufonis* (88066); *Aplectana itzocanensis* (88067); *Cosmocercoides variabilis* (88068); *Falcaustra inglisi* (88069); *Oswaldocruzia pipiens* (88070); *Rhabdias americanus* (88071); *Physaloptera* sp., third stage larvae (88072).

Prevalence and mean abundance ± SD by county are presented in Table 1. *Aplectana itzocanensis* occurred in the small and large intestines; *O. pipiens* was found in the stomach and small and large intestines. Other helminths were site specific: *D. bufonis,* small intestine; *H. kernensis* and *R. americanus,* lungs; *C. variabilis* and *F. inglisi,* large intestines; *Physaloptera* sp. stomach.

None of the helminths found in this study is unique to *B. boreas.* These helminths are generalists which occur in other anurans. *Haematoloechus kernensis* is known previously only from its type host, *Rana aurora,* from California (Ingles 1932). Two of the six North American species of *Haematoloechus* exhibit short extracaecal uterine loops but can be separated on the shape and location of the testes: *H. kernensis* with round almost parallel testes; *H. varioplexis* with elongate oblique testes (Kennedy 1981). *Bufo boreas* represents a new host record for *H. kernensis.*

The monotypic *D. bufonis* is known throughout western North America from species of *Hyla, Bufo, Scaphiopus* and *Spea* (see Douglas 1958; Goldberg and Bursey 1991a,b; Goldberg et al. 1995). Koller and Gaudin (1977) reported *Distoichometra* sp. from *B. boreas* collected in Los Angeles County. Thus, this is the second report of this cestode from southern California from *B. boreas.*

Aplectana itzocanensis is known from species of *Bufo, Gastrophryne, Scaphiopus* and *Spea* from Costa Rica, México and the southwestern United States (Goldberg et al. 1998). The two North American species, *A. incerta* and *A. itzocanensis* are separated on the basis of the number of eggs in gravid females: *A. incerta* with approximately 50 eggs; *A. itzocanensis* with several hundred eggs (Baker 1985). *Bufo boreas* represents a new host record for *A. itzocanensis.*

Cosmocercoides variabilis has been reported from North American salamanders, frogs, lizards, snakes and turtles (see Baker 1987). Some uncertainty exists for its hosts because of confusion between *C. variabilis* and *Cosmocercoides dukae,* a molluscan parasite. Vanderburgh and Anderson (1987) demonstrated that the two species are distinct. The major difference in morphology for the two species is the number of rosette papillae in the male: *C. dukae* with 12 pairs, *C. variabilis* with 14 to 20 pairs. Ingles (1936) reported *C. dukae* from *Taricha torosa*, *Rana aurora* and *B. boreas* from California but illustrated 16 pairs of papillae and for this reason we refer his specimens to *C. variabilis.* We also refer the *Cosmocercoides* sp. of Koller and Gaudin (1977) to *C. variabilis.* Thus, this is the third report of *C. variabilis* from *B. boreas.*

Falcaustra inglisi has been reported from *Rana catesbeiana, Rana clamitans*

Table 1. Helminths from 69 *Bufo boreas* from southern California.

Helminth	Los Angeles County (N = 30)		Orange County (N = 3)		Riverside County (N = 11)		San Bernardino County (N = 25)	
	Prevalence[1] (%)	Mean abundance[2] ± SD	Prevalence (%)	Mean abundance (±SD)	Prevalence (%)	Mean abundance ±SD	Prevalence (%)	Mean abundance ±SD
Trematoda								
Haematoloechus kernensis[3]	—	—	—	—	—	—	28	4.32 ± 9.28
Cestoda								
Distoichometra bufonis	3	0.17 ± 0.91	—	—	—	—	12	0.12 ± 0.33
Nematoda								
Aplectana itzocanensis[3]	—	—	33	0.67 ± 1.15	18	7.55 ± 17.21	16	1.08 ± 2.69
Cosmocercoides variabilis	—	—	—	—	18	1.73 ± 4.15	—	—
Falcaustra inglisi[3]	3	0.03 ± 0.18	—	—	—	—	—	—
Oswaldocruzia pipiens	33	1.87 ± 3.67	—	—	9	0.18 ± 0.60	—	—
Rhabdias americanus	—	—	—	—	—	—	32	1.00 ± 1.87
Physaloptera sp.[3]	—	—	33	2.00 ± 3.46	—	—	—	—

[1] Number of toads infected with one or more individuals of a parasite species divided by the number of toads examined.
[2] Total number of individuals of a parasite species divided by the total number of toads examined.
[3] = new host record.

Table 2. Helminth parasites of *Bufo boreas*.

Helminth	Locality	Prevalence (%)	Reference
Trematoda			
Glypthelmins shastai	California	not given	Ingles 1936
	California	2/115 (2)	Koller and Gaudin 1977
Gorgoderina sp.	California	not given	Ingles 1936
Gorgoderina translucida	Idaho	1/8 (13)	Waitz 1961
Haematoloechus kernensis	California	7/69 (10)	this study
Megalodiscus microphagus	California	not given	Ingles 1936
Phyllodistomum bufonis	Utah	not given	Frandsen and Grundmann 1960
Cestoda			
Distoichometra bufonis	California	19/140 (14)	Koller and Gaudin 1977
	California	4/69 (6)	this study
Nematoda			
Aplectana itzocanensis	California	7/69 (10)	this study
Cosmocercoides variabilis	California	not given	Ingles 1936
	California	40/255 (16)	Koller and Gaudin 1977
	California	2/69 (3)	this study
	Utah	not given	Frandsen and Grundmann 1960
Falcaustra inglisi	California	1/69 (1)	this study
Falcustra pretiosa	California	not given	Walton 1941
Megalobatrachonema gigantica	Utah	not given	Frandsen and Grundmann 1960
Oswaldocruzia pipiens	California	not given	Ingles 1936
	California	119/255 (47)	Koller and Gaudin 1977
	California	11/69 (16)	this study
Rhabdias americanus	California	not given	Ingles 1936
	California	13/255 (5)	Koller and Gaudin 1977
	California	8/69 (12)	this study
Physaloptera sp. (larvae)	California	1/69 (1)	this study

and *Rana septentrionalis* from Ontario, Canada (Baker 1987). The nine North American species of *Falcaustra* (see Baker 1987) are separated by size of spicule and position of caudal papillae. *Falcaustra inglisi* is the only species having 2 pairs of large and 2 pairs of small precloacal papillae. *Bufo boreas* represents a new host record and California a new location record for *F. inglisi*.

All North American specimens of *Oswaldocruzia* have been referred to *O. pipiens* by Baker (1977). This species is widely distributed in North America and has been reported from frogs, toads, salamanders, lizards and tortoises (see Baker 1987). *Oswaldocruzia* sp. was reported from *B. boreas* in California by Koller and Gaudin (1977). This is the second report of *O. pipiens* from *B. boreas*.

Rhabdias americanus was first described from *Bufo americanus* collected in Canada (Baker 1978) and has been reported from species of *Bufo* from the southwestern United States (see Goldberg et al. 1996). In addition, Baker (1978) referred reports of *Rhabdias bufonis* in *Bufo woodhousii* and *Bufo americanus* of eastern North America to *R. americanus*. We refer the reports of *Rhabdias* sp. in *B. boreas* from California (Ingles 1936; Koller and Gaudin 1977) to *R. americanus* because Ingles (1936) in his survey of amphibian parasites reported this *Rhabdias* to be a species other than *Rhabdias joaquinensis* or *Rhabdias ranae;*

R. americanus was not described until 1978 (Baker 1978). This is the third report of *R. americanus* from *B. boreas.*

Third stage larvae of *Physaloptera* sp. are common in toads, but no parasitism by adult physalopterans in toads has been reported (Goldberg et al. 1995). *Bufo boreas* represents a new host record for larvae of *Physaloptera* sp.

Reasons for the patchy distribution of helminths found in this study (Table 1) are unknown. No helminth species occurred in all locations; yet, given general distribution ranges, each helminth species might be expected to be present. Koller and Gaudin (1977) also report similar differences in helminth species distribution for two populations of *B. boreas* from southern California. Likewise, other helminths have been reported from populations of *B. boreas* in California (Table 2), but were not found in this study.

Of the parasites listed in Table 2, the trematodes require an aquatic intermediate host (Smyth and Smyth 1980); the life cycle of the cestode *D. bufonis* is unknown (Hardin and Janovy 1988). With the exception of *Physaloptera* which has an indirect life cycle requiring an insect intermediate host, the nematodes are acquired orally or by skin penetration (direct life cycles) and have moisture sensitive larval stages (Anderson 1992). In either case, indirect or direct life cycle, environmental conditions have a deciding role in patchy distribution patterns by causing local changes in the distribution of intermediate hosts or the hydrologic cycle while not affecting the historical pattern of host distribution. More work will be required to determine the factors responsible for the patchy distribution patterns of parasites within this host; specifically, annual prevalence studies with environmental monitoring for several populations of B. boreas should be initiated.

We thank Robert L. Bezy (Natural History Museum of Los Angeles County) for permission to examine *B. boreas* for helminths.

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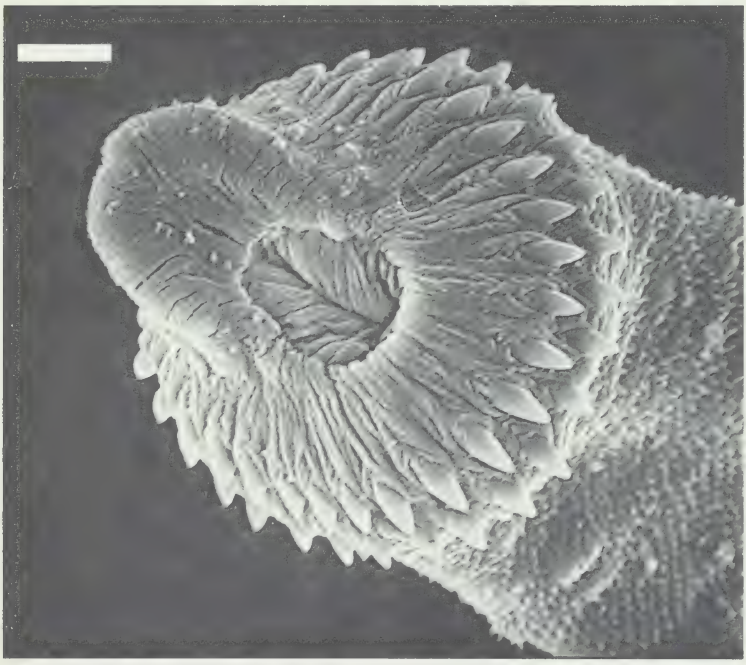

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Checklist of Amphibians and Reptiles on Islands in the Gulf of California, México

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Abstract.—A cross-referenced checklist of the herpetofauna on islands in the Gulf of California is provided which contains 58 additional records and 28 additional islands not reported in the most recent checklist. The taxonomy of the herpetofauna is based on an evolutionary species concept.

Resumen.—Una lista de la herpetofauna de las islas del Golfo de California, México está presentada y contiene 58 registros adicional y 28 islas adicional que no habían reportados en la lista más reciente. La taxonomía de la herpetofauna está basada en un concepto de especie evolutiva.

The islands in the Gulf of California have been heralded to be among North America's most distinctive natural laboratories for broad-based evolutionary studies (e.g., Case and Cody 1983). As such, these islands have received considerable attention from evolutionary biologists of widely varying disciplines, most notably herpetologists (e.g. Case 1975, 1983; Cliff 1954a,b; Dixon 1966; Grismer 1994a,b,c, 1999a,b; Hews 1990a,b; Hollingsworth 1998; Murphy 1983a,b; Petren and Case 1997; Radtkey et al., 1997; Robinson 1972, 1974; Savage 1960; Soulé 1964, 1966; Upton and Murphy 1997; Wilcox 1978). Necessary prerequisites for many evolutionary studies concerned with insular lineages or ecosystems is an understanding of which species are present on the island(s) of concern as well as an appropriate taxonomy that is consistent with their evolutionary history. Grismer (1999b) has revised the taxonomy of the insular herpetofauna of the Gulf of California using the criterion of the evolutionary species concept (Wiley 1978; Frost and Hillis 1990) in an attempt to make it consistent with each taxon's evolutionary history. This paper provides a working, up-to-date checklist of the herpetofauna of the all the islands in the Gulf of California based on the taxonomy of Grismer (1999b).

Since the turn of the century, at least four herpetological checklists concerning the gulf island herpetofauna have been published (Schmidt 1922; Cliff 1954b; Soulé and Sloan 1966; Murphy and Ottley 1984). Although the most recent checklist by Murphy and Ottley (1984) has been extremely useful and is considerably more comprehensive than its predecessors, it is problematic in that it includes numerous taxonomic changes lacking supportive data (see Flores-Villela 1993; Grismer, 1999b), it contains misidentified islands resulting in erroneous records, and it omits many published insular accounts and museum records that were in existence prior to its publication. In this paper, there are 58 additional insular records which were not reported in Murphy and Ottley (1984). These include records reported here for the first time (Appendix I), records from accounts published subsequent to Murphy and Ottley (1984) (i.e., Cryder et al. 1997; Felger

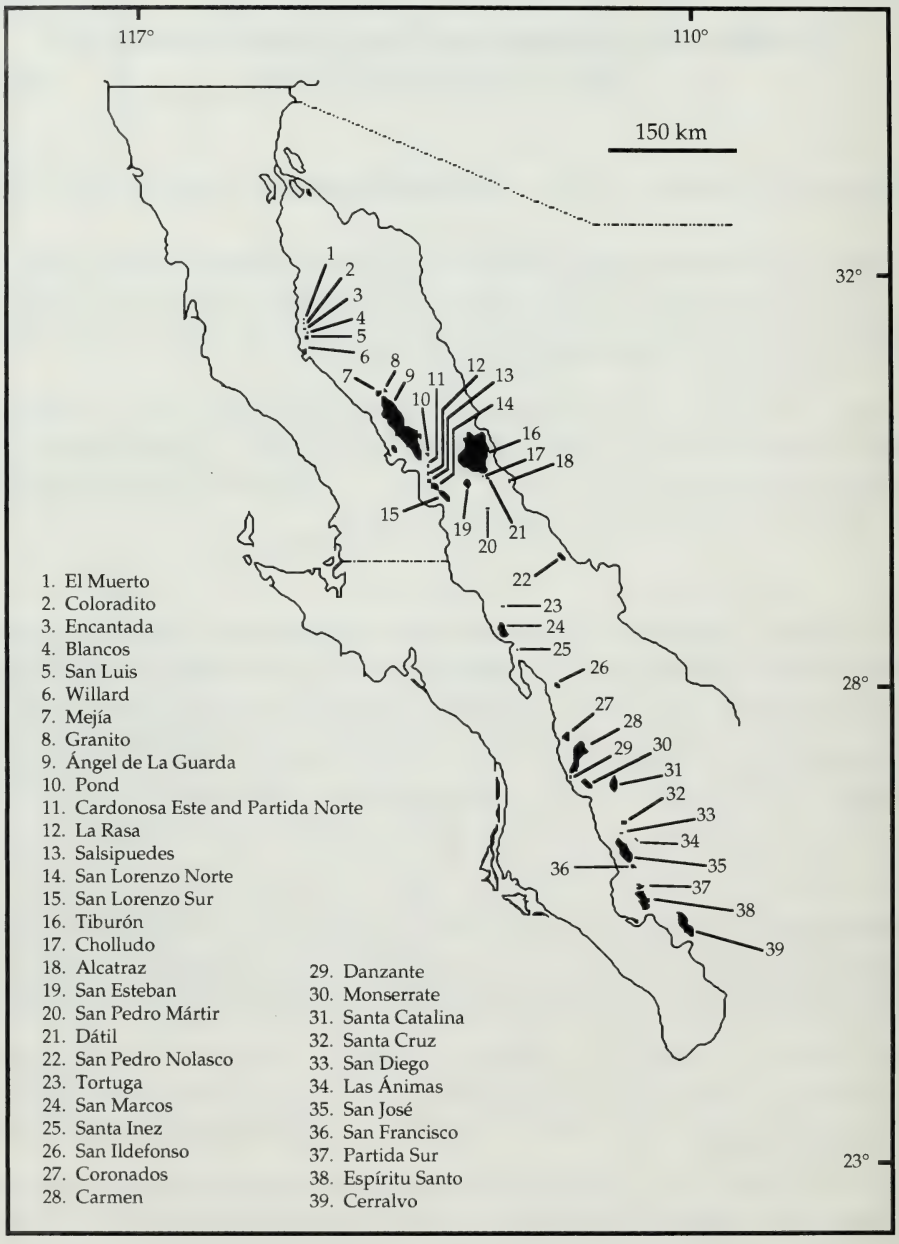

Fig. 1. Location of islands in the Gulf of California, México.

and Moser, 1985; Grismer 1989a,b, 1996a,b; Grismer et al. 1996; Ramírez 1989; Reynoso 1989; Hollingsworth and Grismer 1996; Hollingsworth et al. 1996, 1997; Lava-G. et al. 1993; Mahrdt and Grismer 1995; Wong, 1997; Wong et al. 1995, 1996), and previously existing records (Lowe 1955; Soulé and Sloan 1966) overlooked by Murphy and Ottley (1984; Appendix I). Twenty-eight additional gulf islands are included that were not listed in Murphy and Ottley (1984). Figure 1 illustrates the location of the major islands. Descriptive locations of islands not

figured are provided in Appendix II. Table 1 and Appendix II were compiled from new records from Appendix I, the checklist of Murphy and Ottley (1984), and from literature records subsequent to Murphy and Ottley (1984).

Erroneous or Questionable Insular Records

Malkin (1962) reported *Bufo alvarius* from Isla Tiburón which was followed by Foquette (1970). However, R. Crombie (pers. comm. 1996) informed me that surveys for amphibians on Isla Tiburón revealed only *B. punctatus* and that there were no documented records of *B. alvarius* from Isla Tiburón. It is presumed here that Malkin (1962) mistook *B. punctatus* for *B. alvarius.* Therefore, this record is not included in the checklist.

Duellman (1970) reported a specimen of *Hyla regilla* from Isla Coronados off the east coast of Loreto in the Gulf of California. Isla Coronados is a landbridge, volcanic island that has never been known to have any source of fresh water. Therefore, although a specimen does exist with locality data, the locality is considered here to be dubious.

Felger (1966) reported *Gopherus agassizzii* as occurring on Isla Dátil. However, this sighting has yet to be confirmed with a specimen or voucher photograph. Therefore, its occurrence on Isla Dátil remains in question.

Murphy and Ottley (1984) provided an undocumented report of *Uta stansburiana* from Isla Cholludo. A search of the holdings of five museums (CAS, LACM, MVZ, SDSNH, USNM; museum acronyms follow Leviton et al. 1985) revealed no specimens from Isla Cholludo. Additionally, no *U. stansburiana* were observed on two surveys (6 October 1995 and 25 March 1997) of Isla Cholludo totaling 18 person-hours. Therefore, *U. stansburiana* is presumed to be absent from Isla Cholludo.

Crotalus atrox was first reported from Isla Santa Cruz by Soulé and Sloan (1966). Since that time there has been no indication that it was anything other than *C. atrox.* Stewart et al. (1990), without comment, considered this population to be *C. ruber.* Specimens I have observed in the field (LACM PC 1303) and in museums are all *C. atrox.* Therefore, the report of Stewart et al. (1990) is considered here to be an oversight.

Grismer et al. (1994) placed *Crotalus ruber* in the synonymy of *C. exsul.* A petition was submitted to the International Commission on Zoological Nomenclature to give precedence to *C. ruber* over *C. exsul* (Smith et al. 1998). According to Article 80 of the International Code of Zoological Nomenclature, the most commonly used classification should be employed until a decision has been made by the commission. Because the earlier classification has a wider usage, it is adopted here.

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Table 1. Checklist of the herpetofauna on islands in the Gulf of California, México. Asterisked taxa are insular endemics.

Taxon	Insular locale
ANURA	
Bufonidae	
Bufo punctatus	Cerralvo, Espíritu Santo, Partida Sur, Tiburón
Pelobatidae	
Scaphiopus couchii	Cerralvo, Espíritu Santo, Partida Sur, Tiburón
CHELONIA	
Testudinidae	
Gopherus agassizii	Dátil (?), Tiburón
SQUAMATA (Lizards)	
Crotaphytidae	
Crotaphytus dickersonae	Tiburón
*Crotaphytus insularis**	Ángel de La Guarda
Gambelia wislizenii	Tiburón
Iguanidae	
*Ctenosaura conspicuosa**	Cholludo, San Esteban
Ctenosaura hemilopha	Cerralvo
*Ctenosaura nolascensis**	San Pedro Nolasco
Dipsosaurus dorsalis	Ángel de La Guarda, Carmen, Cerralvo, Coronados, Espíritu Santo, Monserrate, Partida Sur, Santiago, San José, San Luis, San Marcos
*Dipsosaurus catalinensis**	Santa Catalina
Sauromalus ater	Ballena, Danzante, El Coyote, Espíritu Santo, Gallo, Pardo, Partida Sur, San Cosme, San Diego, San Francisco, San José, San Marcos, Santa Cruz, Tiburón, Willard
*Sauromalus hispidus**	Ángel de La Guarda, Cabeza de Caballo, Flecha, Granito, La Ventana, Mejía, Mitlán, Piojo, Pond, San Lorenzo Norte, San Lorenzo Sur, Smith
*Sauromalus klauberi**	Santa Catalina
*Sauromalus slevini**	Carmen, Coronados, Monserrate
*Sauromalus varius**	Roca Lobos, San Esteban
Sauromalus hispidus × *ater* × *varius*	Alcatraz
Phrynosomatidae	
Callisaurus draconoides	Ángel de La Guarda, Carmen, Cerralvo, Coronados, Danzante, Espírirtu Santo, Partida Sur, Patos, San Francisco, San José, San Luis, San Marcos, Santa Inez, Smith, Tiburón

Table 1. Continued.

Taxon	Insular locale
Petrosaurus mearnsi	El Muerto
Petrosaurus repens	Danzante
*Petrosaurus slevini**	Ángel de La Guarda, Mejía
Petrosaurus thalassinus	Espíritu Santo, Partida Sur
Phrynosoma solare	Tiburón
*Sceloporus angustus**	San Diego, Santa Cruz
Sceloporus clarkii	San Pedro Nolasco, Tiburón
*Sceloporus grandaevus**	Cerralvo
Sceloporus hunsakeri	Ballena, Espíritu Santo, Gallo, Partida Sur
*Sceloporus lineatulus**	Santa Catalina
Sceloporus magister	Tiburón
Sceloporus orcutti	Carmen, Coronados, San Francisco, San Ildefonso, San José, San Marcos, Tortuga
Sceloporus zosteromus	Carmen, Coronados, Espíritu Santo, Monserrate, Partida Sur, San José
Urosaurus nigricaudus	Ballena, Carmen, Cayo, Coronados, Danzante, El Coyote, El Requesón, Espíritu Santo, Gallina, Gallo, Gaviota, Islitas, Las Ánimas, Pardo, Partida Sur, San Cosme, San Damian, San Francisco, San José, San Marcos, Tijeras
Urosaurus ornatus	Tiburón
*Uta encantadae**	Encantada, Islotes Blancos
*Uta lowei**	El Muerto
*Uta nolascensis**	San Pedro Nolasco
*Uta palmeri**	San Pedro Mártir
*Uta squamata**	Santa Catalina
Uta stansburiana	Alcatraz, Ángel de La Guarda, Ballena, Bota, Cabeza de Caballo, Cardonosa Este, Carmen, Cerraja, Coronados, Danzante, Dátil, El Pardito, Espíritu Santo, Flecha, Gallo, Granito, Lagartija, La Raza, La Ventana, Las Galeras, Mitlán, Mejía, Monserrate, Partida Norte, Partida Sur, Patos, Piojo, Pond, Roca Lobos, Salsipuedes, San Esteban, San Francisco, San Ildefonso, San José, San Lorenzo Norte, San Lorenzo Sur, San Luis, San Marcos, Smith, Tiburón, Tortuga, Willard
*Uta tumidarostra**	Coloradito
Eublepharidae	
*Coleonyx gypsicolus**	San Marcos
Coleonyx variegatus	Ángel de La Guarda, Coronados, Danzante, Espíritu Santo, Partida Sur, San José, San Marcos, Santa Inez, Tiburón
Gekkonidae	
*Phyllodactylus bugastrolepis**	Santa Catalina
*Phyllodactylus partitus**	Cardonosa Este, Partida Norte
Phyllodactylus homolepidurus	San Pedro Nolasco
Phyllodactylus unctus	Ballena, Cerralvo, Espíritu Santo, Gallina, Gallo, Partida Sur
Phyllodactylus xanti	Alcatraz, Ángel de La Guarda, Carmen, Cayo, Cholludo, Coronados, Danzante, Dátil, El Coyote, El Muerto, El Pardito, La Raza, La Ventana, Las Ánimas, Mejía, Monserrate, Mosca, Pardo, Piojo, Pond, Salsipuedes, San Diego, San Esteban, San Francisco, San Ildefonso, San José, San Lorenzo Norte, San Lorenzo Sur, San Marcos, Santa Cruz, Smith, Tiburón

Table 1. Continued.

Taxon	Insular locale
Teiidae	
*Cnemidophorus bacatus**	San Pedro Nolasco
*Cnemidophorus canus**	Salsipuedes, San Lorenzo Norte, San Lorenzo Sur
*Cnemidophorus carmenensis**	Carmen
*Cnemidophorus catalinensis**	Santa Catalina
*Cnemidophorus celeripes**	San Francisco, San José
*Cnemidophorus ceralbensis**	Cerralvo
*Cnemidophorus danheimae**	San José
*Cnemidophorus espiritensis**	Espíritu Santo, Partida Sur
*Cnemidophorus franciscensis**	San Francisco
Cnemidophorus hyperythrus	Coronados, San Marcos
*Cnemidophorus martyris**	San Pedro Mártir
*Cnemidophorus pictus**	Monserrate
Cnemidophorus tigris	Ángel de La Guarda, Cardonosa Este, Carmen, Coronados, Danzante, Espíritu Santo, Partida Norte, Partida Sur, Pond, San Cosme, San Esteban, San Marcos, Smith, Tiburón
SQUAMATA (Snakes)	
Leptotyphlopidae	
Leptotyphlops humilis	Carmen, Cerralvo, Danzante, San Marcos, Santa Catalina
Boiidae	
Lichanura trivirgata	Ángel de La Guarda, Cerralvo Mejía, San Marcos, Tiburón
Colubridae	
Bogertophis rosaliae	Danzante
Chilomeniscus cinctus	Danzante, Monserrate, San José, San Marcos, Tiburón
*Chilomeniscus punctatissimus**	Espíritu Santo, Partida Sur
*Chilomeniscus savagei**	Cerralvo
Chilomeniscus stramineus	Tiburón
*Eridiphas marcosensis**	San Marcos
Eridiphas slevini	Cerralvo, Coronados, Danzante
*Hypsiglena gularis**	Partida Norte
Hypsiglena torquata	Ángel de la Guarda, Carmen, Cerralvo, Coronados, Danzante, Mejía, Monserrate, Partida Sur, San Esteban, San Francisco, San José, San Lorenzo Sur, San Marcos, Santa Catalina, Smith, Tiburón, Tortuga
*Lampropeltis catalinensis**	Santa Catalina
Lampropeltis getula	Ángel de La Guarda, Cerralvo, Monserrate, Salsipuedes, San Esteban, San Lorenzo Norte, San Lorenzo Sur, San Pedro Mártir, San Pedro Nolasco, Tortuga
*Masticophis barbouri**	Espíritu Santo, Partida Sur
Masticophis bilineatus	Tiburón
Masticophis flagellum	Carmen, Cerralvo, Coronados, Danzante, Dátil, Espíritu Santo, Monserrate, Partida Sur, San Ildefonso, San José, San Marcos, Tiburòn
*Masticophis slevini**	San Esteban
Phyllorhynchus decurtatus	Ángel de La Guarda, Cerralvo, Monserrate, San José, San Marcos
Pituophis melanoleucus	Tiburón
Pituophis vertebralis	San José
*Rhinocheilus etheridgei**	Cerralvo

Table 1. Continued.

Taxon	Insular locale
Salvadora hexalepis	Espíritu Santo, San José, Tiburón
Sonora semiannulata	San José, San Marcos
Tantilla planiceps	Carmen
Trimorphodon biscutatus	Cerralvo, Danzante, El Muerto, San José, San Marcos, Tiburón
Elapidae	
Micruroides euryxanthus	Tiburón
Viperidae	
*Crotalus angelensis**	Ángel de La Guarda
Crotalus atrox	Dátil, San Pedro Mártir, Santa Cruz, Tiburón
*Crotalus catalinensis**	Santa Catalina
Crotalus cerastes	Tiburón
Crotalus enyo	Carmen, Cerralvo, Coronados, Espíritu Santo, Pardo, Partida Sur, San Francisco, San José, San Marcos
*Crotalus estebanensis**	San Esteban
*Crotalus lorenzoensis**	San Lorenzo Sur
Crotalus mitchellii	Carmen, Cerralvo, Espíritu Santo, Monserrate, Partida Sur, Piojo, Salsipuedes, San José, Smith
*Crotalus muertensis**	El Muerto
Crotalus molossus	Tiburón
Crotalus ruber	Ángel de La Guarda, Danzante, Monserrate, Pond, San José, San Marcos
Crotalus tigris	Tiburón
*Crotalus tortugensis**	Tortuga

Appendix I

New insular records of amphibians and reptiles on islands in the Gulf of California, México are listed below. The records are followed by voucher photograph numbers (LACM PC) or museum catalogue numbers and, when possible, the date the specimens were observed or collected. Literature records or museum specimens present prior to 1984 not reported by Murphy and Ottley (1984) are followed by a literature citation or museum catalogue number, respectively. Museum acronyms follow Leviton et al. (1985).

ANURA

Pelobatidae. *Scaphiopus couchii.*—Isla Tiburón, Sonora; Felger and Moser (1985).

CHELONIA

Testudinidae. *Gopherus agassizii.*—Isla Dátil, Sonora; Felger (1966); questionable.

SQUAMATA (Lizards)

Iguanidae. *Dipsosaurus dorsalis.*—Isla Santiago (1 km north of Loreto). *Sauromalus ater.*—Isla Gallo, BCS, LACM PC 1275, 31 August 1987; Isla San Cosme, BCS, LACM PC 1276, 4 April 1993; Isla El Coyote (in Bahía Concepción), BCS, LACM PC 1277, 5 June 1987; Isla Willard, BC, fecal material, 18 December 1986. *Sauromalus hispidus.*—Islas Flecha and Mitlán, BC (scat recorded by G. A. Polis; pers. comm. 30 June 1991).

Phrynosomatidae. *Callisaurus draconoides.*—Isla Patos, Sonora, SDSNH 46427–28. *Sceloporus hunsakeri.*—Isla Gallo, BCS, LACM PC 1278, 31 August 1987. *Urosaurus nigricaudus.*—Isla Cayo, BCS, LACM PC 1279, 23 June 1992; Isla El Coyote, BCS, LACM PC 1280, 5 June 1987; Isla Gallo, BCS, LACM PC 1281, 31 August 1987; Isla Requesón, BCS, LACM PC 1282, 10 August 1988; Islas San Cosme and San Damian, BCS, LACM PC 1283 and 1284, respectively, 4 April 1993. *Uta stansburiana.*—Isla Bota, LACM PC 1285, 30 June 1991; Isla Cabeza de Caballo, BC, LACM PC 1286, 26 April 1989; Isla Cardonosa Este, LACM PC 1287; Isla Cerraja, BC, LACM PC 1288, 30

June 1991; Isla Dátil, Sonora, Felger (1966); Isla Flecha, BC, LACM PC 1290, 30 June 1991; Isla Lagartija, BC, LACM PC 1291, 7 October 1994; Isla Mitlán, BC, G. Polis (pers. comm., 5 June 1992); Isla Pata, BC, LACM PC 1292, 30 June 1991; Isla Roca Lobos, BC, LACM PC 1293, 7 October 1994; Isla Willard, BC, LACM PC 1294, 18 December 1986.

Gekkonidae. *Phyllodactylus partitus.*—Isla Cardonosa Este, BC, LACM PC 1295, 7 October 1994. *Phyllodactylus unctus.*—Isla Gallo, BCS, LACM PC 1296, 31 August 1987. *Phyllodactylus xanti.*—Isla Cholludo, Sonora, Felger (1966); Isla El Coyote, BCS, Dixon (1966); Isla Moscas (in Bahía Concepción) BCS, Dixon (1966); Isla Smith, BC, LACM 131406-12.

Teiidae. *Cnemidophorus tigris.*—Isla Cardonosa Este, BC; LACM PC 1297, 7 October 1994; Isla San Cosme, BCS, LACM PC 1298, 8 April 1993.

SQUAMATA (Snakes)

Colubridae. *Chilomeniscus stramenius.*—Isla Tiburón, Sonora, Felger (1966). *Masticophis flagellum.*—Isla Dátil, Sonora, Felger (1966). *Salvadora hexalepis.*—Isla Espíritu Santo, BCS, CAS 146563–64. Isla El Muerto, BC, LSUHC 4000, 26 March, 1998, shed skin.

Viperidae. *Crotalus atrox.*—Isla Dátil, Sonora, Lowe (1955). *Crotalus mitchellii.*—Isla Cabeza de Caballo, BC, G. A. Polis (pers. comm., 1993).

Appendix II

Checklists of the herpetofauna of the islands in the Gulf of California, México. Less commonly used island names are listed in parentheses. Order of species follows Table 1. Asterisked taxa are insular endemics.

Isla Alcatraz. (Isla Pelícano). *Sauromalus hispidus* × *ater* × *varius, Uta stansburiana, Phyllodactylus xanti.*

Isla Ángel de La Guarda. *Crotaphytus insularis*, Dipsosaurus dorsalis, Sauromalus hispidus*, Callisaurus draconoides, Petrosaurus slevini*, Uta stansburiana, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus tigris, Lichanura trivirgata, Hypsiglena torquata, Lampropeltis getula, Phyllorhynchus decurtatus, Crotalus angelensis*, Crotalus ruber.*

Isla Ballena. (0.5 km W of Isla Espíritu Santo). *Sauromalus ater, Sceloporus hunsakeri, Urosaurus nigricaudus, Uta stansburiana, Phyllodactylus unctus.*

Isla Bota. (within Bahía de Los Ángeles, BC). *Uta stansburiana.*

Isla Cabeza de Caballo. (within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Uta stansburiana, crotalus mitchellii.*

Isla Cardonosa Este. (Isla Cardonosa; 0.5 km NE of Isla Partida Norte). *Uta stansburiana, Phyllodactylus partitus*, Cnemidophorus tigris.*

Isla Carmen. *Dipsosaurus dorsalis, Sauromalus slevini*, Callisaurus draconoides, Sceloporus orcutti, Sceloporus zosteromus, Urosaurus nigricaudus, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus carmenensis*, Cnemidophorus tigris, Leptotyphlops humilis, Hypsiglena torquata, Masticophis flagellum, Tantilla planiceps, Crotalus enyo, Crotalus mitchellii.*

Isla Cayo. (within Bahía Concepción, BCS). *Urosaurus nigricaudus, Phyllodactylus xanti.*

Isla Cerraja. (within Bahía de Los Ángeles, BC). *Uta stansburiana.*

Isla Cerralvo. *Bufo punctatus, Scaphiopus couchii, Ctenosaura hemilopha, Dipsosaurus dorsalis, Callisaurus draconoides, Sceloporus grandaevus*, Phyllodactylus unctus; Cnemidophorus ceralbensis*, Leptotyphlops humilis, Lichanura trivirgata, Chilomeniscus savagei*, Eridiphas slevini, Hypsiglena torquata, Lampropeltis getula, Masticophis flagellum, Phyllorhynchus decurtatus, Rhinocheilus etheridgei*, Trimorphodon biscutatus, Crotalus enyo, Crotalus mitchellii.*

Isla Cholludo. (Isla Lobos, Son.; Isla Roca Foca; between islas Turners and Tiburón). *Ctenosaura conspicuosa*, Phyllodactylus xanti.*

Isla Coloradito. (Isla Lobos, BC; Lobera). *Uta tumidarostra*.*

Isla Coronados. *Dipsosaurus dorsalis, Sauromalus slevini*, Callisaurus draconoides, Sceloporus orcutti, Sceloporus zosteromus, Urosaurus nigricaudus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus hyperythrus, Cnemidophorus tigris, Eridiphas slevini, Hypsiglena torquata, Masticophis flagellum, Crotalus enyo.*

Isla Danzante. *Sauromalus ater, Callisaurus draconoides, Petrosaurus repens, Urosaurus nigricaudus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus tigris, Leptotyphlops humilis, Bogertophis rosaliae, Chilomeniscus cinctus,. Eridiphas slevini, Hypsiglena torquata, Masticophis flagellum, Trimorphodon biscutatus, Crotalus ruber.*

Isla Dátil. (Isla Turners). *Gopherus agassizii* (?), *Uta stansburiana, Phyllodactylus xanti, Masticophis flagellum, Crotalus atrox.*

Isla El Coyote. (within Bahía Concepción, BCS). *Sauromalus ater, Urosaurus nigricaudus, Phyllodactylus xanti.*

Isla El Muerto. (Isla Miramar; Link). *Petrosaurus mearnsi, Phyllodactylus xanti, Uta lowei*, Trimorphodon biscutatus, Crotalus muertensis*.*

Isla El Pardito. (Isla Coyote). *Uta stansburiana, Phyllodactylus xanti.*

Isla El Requesón. (within Bahía Concepción, BCS). *Urosaurus nigricaudus.*

Isla Espíritu Santo. *Bufo punctatus, Scaphiopus couchii, Dipsosaurus dorsalis, Sauromalus ater, Callisaurus draconoides, Petrosaurus thalassinus, Sceloporus hunsakeri, Sceloporus zosteromus, Urosaurus nigricaudus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus unctus, Cnemidophorus espiritensis*, Cnemidophorus tigris, Chilomeniscus punctatissimus*, Masticophis barbouri*, Masticophis flagellum, Salvadora hexalepis, Crotalus enyo, Crotalus mitchellii.*

Isla Encantada. *Uta encantadae*.*

Isla Flecha. (within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Uta stansburiana.*

Isla Gallina. (0.5 km W of Isla Espíritu Santo, BCS). *Urosaurus nigricaudus, Phyllodactylus unctus.*

Isla Gallo. (0.5 km W of Isla Espíritu Santo). *Sauromalus ater, Sceloporus hunsakeri, Urosaurus nigricaudus, Uta stansburiana, Phyllodactylus unctus.*

Isla Gaviota. (0.5 km N of Pichilingue, BCS). *Urosaurus nigricaudus.*

Isla Granito. *Sauromalus hispidus*, Uta stansburiana.*

Isla Islitas. (11.5 km S of Puerto Escondido, BCS). *Urosaurus nigricaudus.*

Isla Lagartija. (0.25 km N of Isla Salsipuedes). *Uta stansburiana.*

Isla La Raza. *Uta stansburiana, Phyllodactylus xanti.*

Isla La Ventana. (Isla Nuevo Amor; within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Uta stansburiana, Phyllodactylus xanti.*

Isla Las Ánimas. (BCS). *Urosaurus nigricaudus, Phyllodactylus xanti.*

Isla Las Galeras. (there are two islands, east and west; 3 km N of Isla Monserrate). *Uta stansburiana.*

Isla Mejía. *Sauromalus hispidus*, Petrosaurus slevini*, Uta stansburiana, Phyllodactylus xanti, Lichanura trivirgata, Hypsiglena torquata.*

Isla Mitlán. (within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Uta stansburiana.*

Isla Monserrate. (Isla Monserrat; Monserrato). *Dipsosaurus dorsalis, Sauromalus slevini*, Sceloporus zosteromus, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus pictus*, Chilomeniscus cinctus, Hypsiglena torquata, Lampropeltis getula, Masticophis flagellum, Phyllorhynchus decurtatus, Crotalus mitchellii, Crotalus ruber.*

Isla Moscas. (within Bahía Concepción, BCS; Dixon, 1966). *Phyllodactylus xanti.*

Isla Pardo. (13.5 km S of Puerto Escondido, BCS). *Sauromalus ater, Urosaurus nigricaudus, Phyllodactylus xanti, Crotalus enyo.*

Isla Partida Norte. (Isla Partida; Cardonosa). *Uta stansburiana, Phyllodactylus partitus, Cnemidophorus tigris, Hypsiglena gularis*.*

Isla Partida Sur. *Bufo punctatus, Scaphiopus couchii, Dipsosaurus dorsalis, Sauromalus ater, Callisaurus draconoides, Petrosaurus thalassinus, Sceloporus hunsakeri, Scelporus zosteromus, Urosaurus nigricaudus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus unctus, Cnemidophorus espiritensis*, Cnemidophorus tigris, Chilomeniscus punctatissimus*, Hypsiglena torquata, Masticophis barbouri*, Masticophis flagellum, Crotalus enyo, Crotalus mitchellii.*

Isla Pata. (within Bahía de Los Ángeles, BC). *Uta stansburiana.*

Isla Patos. (16 km north of Isla Tiburón, SON). *Callisaurus draconoides, Uta stansburiana.*

Isla Piojo. (within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Uta stansburiana, Phyllodactylus xanti, Crotalus mitchellii.*

Isla Pond. (Isla Estanque; La Víbora). *Sauromalus hispidus*, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus tigris, Crotalus ruber.*

Isla Roca Lobos. (0.25 km SW of north end of Isla Salsipeudes). *Sauromalus varius*, Uta stansburiana.*

Isla Salsipuedes. *Uta stansburiana, Phyllodactylus xanti, Cnemidophorus canus*, Lampropeltis getula, Crotalus mitchellii.*

Isla Santiago. (0.25 km W of Isla Coronados, BCS). *Dipsosaurus dorsalis.*

Isla San Cosme. (13 km W of Isla Monserrate). *Sauromalus ater, Urosaurus nigricaudus, Cnemidophorus tigris.*

Isla San Damian. (12 km W of Isla Monserrate). *Urosaurus nigricaudus.*

Isla San Diego. *Sauromalus ater, Sceloporus angustus*, Phyllodactylus xanti.*

Isla San Esteban. *Ctenosaura conspicuosa*, Sauromalus varius, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus tigris, Hypsiglena torquata, Lampropeltis getula, Masticophis slevini*, Crotalus estebanensis*.*

Isla San Francisco. *Sauromalus ater, Callisaurus draconoides, Sceloporus orcutti, Urosaurus nigricaudus, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus celeripes*, Cnemidophorus franciscensis*, Hypsiglena torquata, Crotalus enyo.*

Isla San Ildefonso. *Sceloporus orcutti, Uta stansburiana, Phyllodactylus xanti, Masticophis flagellum.*

Isla San José. *Dipsosaurus dorsalis, Sauromalus ater, Callisaurus draconoides, Sceloporus orcutti, Sceloporus zosteromus, Urosaurus nigricaudus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus celeripes*, Cnemidophorus danheimae*, Chilomeniscus cinctus, Hypsiglena torquata, Masticophis flagellum, Phyllorhynchus decurtatus, Pituophis vertebralis, Salvadora hexalepis, Sonora semiannulata, Trimorphodon biscutatus, Crotalus enyo, Crotalus mitchellii, Crotalus ruber.*

Isla San Lorenzo Norte. (Isla Las Ánimas, BC). *Sauromalus hispidus*, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus canus*, Lampropeltis getula.*

Isla San Lorenzo Sur. (Isla San Lorenzo). *Sauromalus hispidus*, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus canus*, Hypsiglena torquata, Lampropeltis getula, Crotalus lorenzoensis*.*

Isla San Luis. (Isla Encantada Grande; Salvatierra; San Luis Gonzaga). *Dipsosaurus dorsalis, Callisaurus draconoides, Uta stansburiana.*

Isla San Marcos. *Dipsosaurus dorsalis, Sauromalus ater, Callisaurus draconoides, Sceloporus orcutti, Urosaurus nigricaudus, Uta stansburiana, Coleonyx gypsicolus*, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus hyperythrus, Cnemidophorus tigris, Leptotyphlops humilis, Lichanura trivirgata, Chilomeniscus cinctus, Eridiphas marcosensis*, Hypsiglena torquata, Masticophis flagellum, Phyllorhynchus decurtatus, Sonora semiannulata, Trimorphodon biscutatus, Crotalus enyo, Crotalus ruber.*

Isla San Pedro Mártir. *Uta palmeri*, Cnemidophorus martyris*, Lampropeltis getula, Crotalus atrox.*

Isla San Pedro Nolasco. *Ctenosaura nolascensis*, Sceloporus clarkii, Uta nolascensis*, Phyllodactylus homolepidurus, Cnemidophorus bacatus*, Lampropeltis getula.*

Isla Santa Catalina (Isla Catlán; Catalana; Catalano). *Dipsosaurus catalinensis*, Sauromalus klauberi*, Sceloporus lineatulus*, Uta squamata*, Phyllodactylus bugastrolepis*, Cnemidophorus catalinensis*, Leptotyphlops humilis, Hypsiglena torquata, Lampropeltis catalinensis*, Crotalus catalinensis*.*

Isla Santa Cruz. *Sauromalus ater, Sceloporus angustus, Phyllodactylus xanti, Crotalus atrox.*

Isla Smith. (Isla Coronado; within Bahía de Los Ángeles, BC). *Sauromalus hispidus*, Callisaurus draconoides, Uta stansburiana, Phyllodactylus xanti, Cnemidophorus tigris, Hypsiglena torquata, Crotalus mitchellii.*

Isla Tijeras. (13 km S of Puerto Escondido, BCS). *Urosaurus nigricaudus.*

Isla Tiburón. *Bufo punctatus, Scaphiopus couchii, Gopherus agassizii, Crotaphytus dickersonae, Gambelia wislizenii, Sauromalus ater, Callisaurus draconoides, Phrynosoma solare, Sceloporus clarkii, Sceloporus magister, Urosaurus ornatus, Uta stansburiana, Coleonyx variegatus, Phyllodactylus xanti, Cnemidophorus tigris, Lichanura trivirgata, Chilomeniscus cinctus, Chilomeniscus stramineus, Hypsiglena torquata, Masticophis bilineatus, Masticophis flagellum, Pituophis melanoleucus, Salvadora hexalepis, Trimorphodon biscutatus, Micruroides euryxanthus, Crotalus atrox, Crotalus cerastes, Crotalus molossus, Crotalus tigris.*

Isla Tortuga. *Sceloporus orcutti, Uta stansburiana, Hypsiglena torquata, Lampropeltis getula, Crotalus tortugensis*.*

Isla Willard. (within Bahía de San Luis Gonzaga, BC). *Sauromalus ater, Uta stansburiana.*

Islas Santa Inez. (three islands; records from southernmost island only). *Callisaurus draconoides, Coleonyx variegatus.*

Islotes Blancos. (0.25 km SE of Isla Encantada). *Uta encantadae*.*

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Identification and Distribution of Spiny Pocket Mice (*Chaetodipus*) in Cismontane Southern California

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Abstract.—The San Diego Pocket Mouse (*Chaetodipus fallax*) and California Pocket Mouse (*C. californicus*) frequently are confused with each other. The shorter, more rounded ears of San Diego Pocket Mice, and to a lesser extent their smaller hind feet, are the best external means of distinguishing them from California Pocket Mice. The two species are largely allopatric, *californicus* to the north and *fallax* to the south, but their ranges overlap somewhat in cismontane southern California. California Pocket Mice occupy higher elevations in this area and farther south, whereas San Diego Pocket Mice are generally found at lower elevations and extend no farther north than southeastern Los Angeles County.

Two species of spiny pocket mouse (*Chaetodipus*; formerly considered a subgenus of *Perognathus*; Hafner and Hafner 1983) coexist in cismontane southern California. The California Pocket Mouse (*C. californicus*) occurs from central California to the mountains of northern Baja California, and the San Diego Pocket Mouse (*C. fallax*) occurs from southwestern California to northwestern Baja California Sur (Hall 1981, Schmidly et al. 1993, Williams et al. 1993). Based upon our own experiences in the field, and our examination of museum specimens and the scientific literature, it is clear that these species often have been confused and misidentified. This note is intended to draw attention to this issue, and was prepared with biological consultants primarily in mind. More than any other group, they are charged with documenting the status of wildlife in this rapidly developing region. Moreover, they are among the least likely to produce specimen material in their work. Although we are aware of no evidence suggesting these species are threatened at this time, two subspecies under review here (*C. c. femoralis* and *C. f. fallax*) were Category-2 candidates for federal listing as threatened or endangered (Federal Register 59:58982–59028) before that category was eliminated in 1995. Given the propensity for heteromyids to populate such lists, these species may once again receive attention by the regulatory wildlife agencies. If so, reliable data for their occurrence and distribution will be vital to management planning.

Methods

We obtained ear (to the notch) and hind foot measurements for all specimens of these two species taken from Pacific coastal drainages in southwestern California housed in the Natural History Museum of Los Angeles County (LACM; n = 413), San Diego Natural History Museum (SDNHM; n = 252), California Academy of Sciences (CAS; n = 37), and the San Bernardino County Museum

Table 1. Comparisons of ear length (at the notch) and hind foot length between *Chaetodipus californicus* and *Chaetodipus fallax fallax*.

	C. californicus	*C. f. fallax*
ear_{notch}		
sample size	n = 1,083	n = 387
mean ± SD	11.44 ± 0.88 mm	8.45 ± 0.79 mm
	(t = 59.01, $P < 0.0001$, d.f. = 1,468)	
range	8–14 mm	6–10 mm
coefficient of variation	0.08395	0.09436
hind foot		
sample size	n = 347	n = 373
mean ± SD	25.16 ± 1.42 mm	23.36 ± 1.18 mm
	(t = 18.63, $P < 0.0001$, d.f. = 718)	
range	21–30 mm	20–27 mm
coefficient of variation	0.05641	0.05057

(SBCM; n = 17). We recorded measurements from the original specimen tags unless we had reason to believe they were in error (e.g., ear measurements from the crown), in which case we remeasured the ear if possible, but generally disregarded foot measurements due to the difficulty of remeasuring them on dried specimens. Measurements of pocket mice live-trapped by Erickson and others in the course of consulting work from 1994–1997, primarily in southern Orange and northern San Diego counties (LSA unpublished data; n = 751) also were used in our analysis.

We compared mean lengths of ear and hind foot between the two species using standard t-tests. We performed a canonical discriminant function analysis to examine the degree to which we could distinguish the species based only on these two mensural characters. Prior probabilities for groups classification were set to one-half. Correct placement of individuals to species was determined using both jacknifed classification percentages and Mahalanobis D^2 values with their associated posterior probabilities of correct classification. Statistical analyses were performed using BMDP Statistical Software ver. PC-90.

In addition to standard reference works (i.e., Grinnell 1933, McLaughlin 1959, Huey 1964, Bond 1977, Hall 1981) and localities listed on the specimens examined, we used our own trapping records and those maintained by the Orange County Vector Control District (OCVCD), data from the Museum of Vertebrate Zoology, University of California, Berkeley (MVZ) and Field Museum of Natural History (Chicago) collections, and the reports of fellow investigators to formulate general distributional patterns.

Results

Identification.—Cismontane southern California examples of these species differ significantly in length of ear (to the notch) and in length of hind foot (Table 1). These two mensural characters were combined to yield two discriminant functions:

Table 2. Jackknifed classification resulting from a canonical discriminant function analysis of lengths of ear and hind foot of *Chaetodipus californicus* and *Chaetodipus fallax fallax*.

Group	% correct	Number of cases classified into group	
		californicus	*fallax*
californicus	92.7	319	25
fallax	97.9	8	365
Total	95.4	327	390

$$californicus = 13.4712(\text{hind foot}) + 11.09899(\text{ear}_{\text{notch}}) - 234.0003$$

$$fallax = 12.87714(\text{hind foot}) + 7.33506(\text{ear}_{\text{notch}}) - 182.0511$$

These functions correctly classified 95% of the individuals we examined (Table 2). Only one-third as many individual *fallax* were misclassified compared to misclassifications of *californicus*. Based on an examination of posterior probabilities of correct classification, the majority of misclassified *californicus* were immatures, suggesting that these animals had not yet attained full adult size in ear length and hind foot length. In any case, scores for these species on the first canonical discriminant function axis formed a distinctly bimodal distribution, and virtually all of the misclassified individuals were near the valley between the two peaks (Figure 1). Thus, the above formulas can be used to classify reliably virtually all individuals of these two species of *Chaetodipus* based only on their ear length at notch and their hind foot length.

Even without statistical procedures, California Pocket Mice and San Diego Pocket Mice are readily distinguished by the length and shape of their ears. The greater ear length of *californicus* is not merely the result of the species' slightly larger size. The width of the ears do not appear to be appreciably different, so the length of *californicus* imparts a nearly parallel-edged, elliptical shape com-

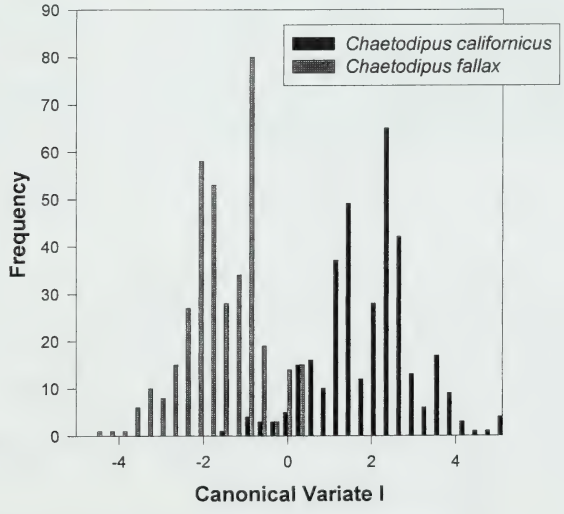

Fig. 1. Mensural statistics; see text.

Fig. 2. Ears of San Diego (*Chaetodipus fallax*; a) and California (*C. californicus*; b) pocket mice. Note the nearly parallel-sided elliptical shape of the latter compared to the nearly round shape of the former. Drawing from Osgood (1900).

pared to the nearly round ears of *fallax* (Figure 2). Even very young *californicus,* with ear lengths more typical of *fallax,* can be identified by ear shape. Hind foot measurements are also significantly different in these two species, but the difference is more proportional to their difference in overall size and there is considerable overlap. In addition to these external characteristics, and beyond the scope of this paper, these species may be distinguished by the shape of their skulls (Hall 1981, Williams et al. 1993) and apparently the presence (*californicus*) or absence (*fallax*) of white spinous hairs on the shoulders (S. J. Montgomery in litt.).

California Pocket Mouse distribution.—This species is primarily found in the Upper Sonoran and Transition life zones (Grinnell 1933, Bond 1977). It occurs at low to moderate elevations in central California, occurs primarily at moderate elevations in southern California, and is restricted to high elevations at the southern end of its range in the Sierra San Pedro Mártir.

Three subspecies of California Pocket Mouse have been described from southern California: *C. c. dispar, C. c. bernardinus,* and *C. c. femoralis* (Figure 3). *C. c. bernardinus* is found primarily in chaparral at moderate to high elevations (750–2100 m) in the San Bernardino, San Jacinto, and eastern San Gabriel mountains of Los Angeles, San Bernardino, and Riverside counties (Grinnell 1933); note that Williams et al. (1993) erroneously excluded the San Jacinto Mountains from the range of this subspecies. A specimen labeled *bernardinus* from a low elevation site at the eastern edge of the Chino Hills in extreme northwestern Riverside County (MVZ 132520) is from outside the published range of the taxon, but was apparently examined by Seth Benson (J. L. Patton pers. comm.), who first described the subspecies (Benson 1930). The locality fits better with the southeastern range of *dispar* described below.

The southern limits of *dispar* and the northern limits of *femoralis* are unclear.

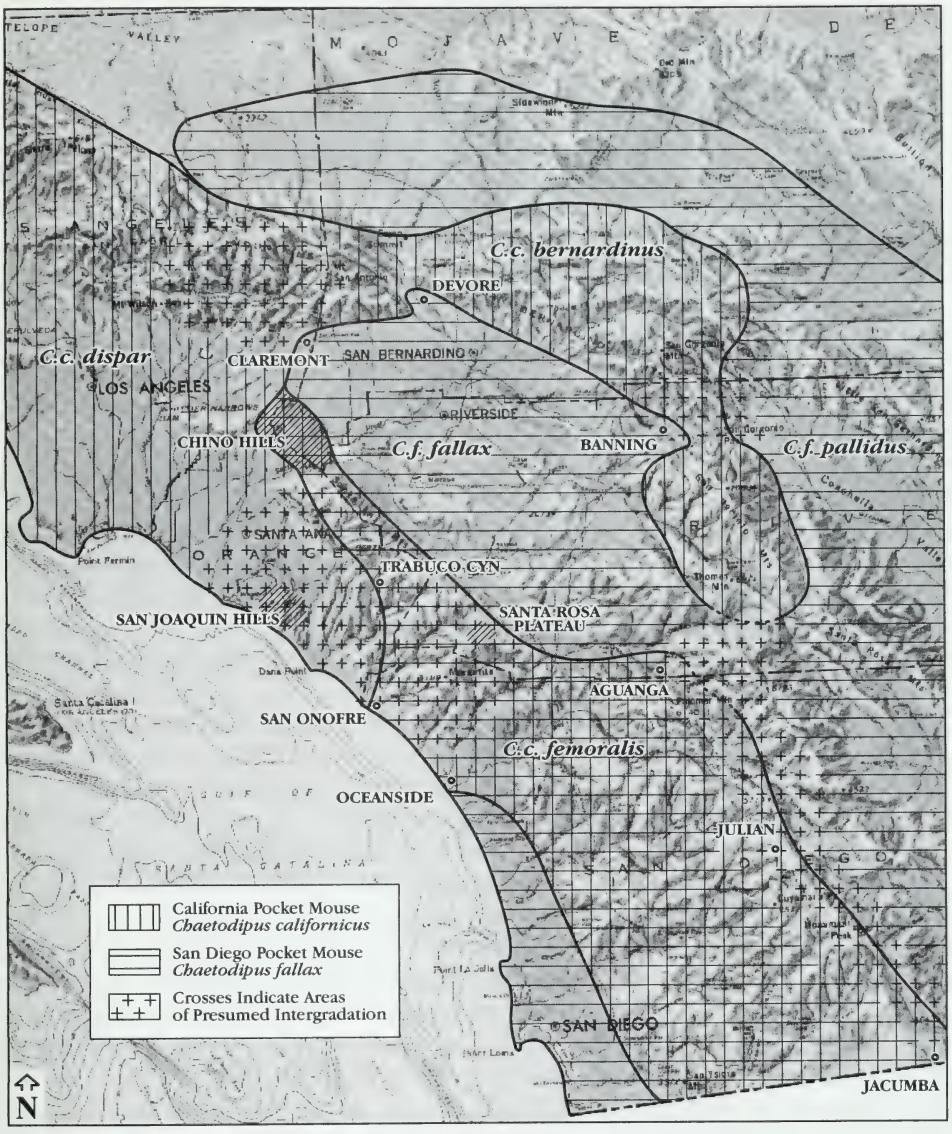

Fig. 3. Approximate distribution of two species of pocket mice in southwestern California.

Grinnell (1933) and Williams et al. (1993) described the range of *dispar* as extending south only to Los Angeles County, and the California range of *femoralis* as limited to San Diego County, thus ignoring all of Orange County. Specimens in MVZ labeled *dispar* come from the southern foothills of the San Gabriel Mountains (Vaughan 1954) and the Palos Verdes Peninsula in Los Angeles County, and near Laguna Beach, Orange County. MVZ specimens labeled *femoralis* extend north to the vicinity of Las Pulgas Creek, San Diego County and Aguanga in southwestern Riverside County. Pequegnat (1951) considered the Santa Ana Mountains to represent an intergradation zone between these two subspecies; he

identified most specimens from there as *dispar,* but considered three specimens representative of *femoralis.*

California Pocket Mice have been trapped throughout the undeveloped low-lying portions of Orange County (OCVCD, LSA, and Patten unpubl. data) upwards to Santiago Peak (Pequegnat 1951), but are essentially unknown in the valleys of western Riverside and southwestern San Bernardino counties (SBCM, pers. obs.). In San Diego County, *californicus* has been collected on the coast south to Oceanside (Hall 1981; MVZ and LSA unpubl. data), but farther south has been found only at interior sites east to the desert slopes of the mountains.

San Diego Pocket Mouse distribution.—The more southerly distributed San Diego Pocket Mouse is primarily resident in the Lower Sonoran Life Zone, and thus is generally restricted to relatively low elevations (exceptionally to 1800 m on the north side of the San Bernardino Mountains) throughout its range (Grinnell 1933, Pequegnat 1951, Vaughan 1954, Huey 1964, Bond 1977). San Diego Pocket Mice are apparently widespread throughout western Baja California, south to extreme northwestern Baja California Sur (Huey 1964, Hall 1981).

Two subspecies are found in southern California: *C. f. pallidus* is restricted to the western deserts, north to northeastern Los Angeles County and nominate *fallax* is found south and west of the mountains (Grinnell 1933, Hall 1981). A skeletal specimen labeled *pallidus* from Devore, San Bernardino County (MVZ 158943) is from an area outside the biogeographical limits of the subspecies and here is considered dubious.

San Diego Pocket Mice have been collected at scattered localities throughout the lowlands of western San Diego County all the way to San Onofre (Grinnell 1933) and the mouth of San Mateo Creek (LSA unpubl. data) on the coast. To the north, *fallax* has been found in Orange County only locally in the foothills of the Santa Ana Mountains (Pequegnat 1951, Bontrager 1975; MVZ, OCVCD and Patten unpubl. data) north to the Santa Ana River Canyon (MVZ) and Chino Hills (Patten unpubl. data). We examined two purported *fallax* specimens from the San Joaquin Hills, Orange County (University of California, Irvine Museum of Systematic Biology) and found them to be typical *californicus*; one had been relabeled as such. The specimens have since been deposited at MVZ (uncataloged at this time), where their identities were confirmed by J. L. Patton (pers. comm.). Two additional specimens from the same locality (UCIMSB 274 and 282; now in the Museum of Wildlife and Fisheries Biology at the University of California, Davis) have ear measurements of 9 and 10 mm. Only *californicus* had been found previously in the San Joaquin Hills (Pequegnat 1951; MVZ) or subsequently during extensive trapping since at least 1990 (LSA and OCVCD unpubl. data). *C. f. fallax* is widespread in the valleys of western Riverside and southwestern San Bernardino counties (pers. obs.) and extends northwest to the vicinity of Claremont, Los Angeles County (Hall 1981, Williams et al. 1993). At the southern base of the San Gabriel Mountains, Vaughan (1954) reported *fallax* below 570 m, and *californicus* had replaced *fallax* by ca. 610 m at a site north of Etiwanda (LSA unpublished data). In the Santa Ana Mountains, Pequegnat (1951) found *fallax* only below 610 m ("much more abundant on the interior slopes"), and Bontrager (1973) found *fallax* and *californicus* coexisting at three of his study plots (elevation 400–670 m) on the Santa Rosa Plateau, Riverside County.

Discussion

The different ear proportions of these species have been known for at least 100 years (Figure 2 first appeared in 1900) and *fallax* was known formerly as the Short-eared Pocket Mouse. Nevertheless, we believe this review is warranted in light of the confusion between these species that we have witnessed in southern California. We admit to misidentifying numerous animals ourselves before gaining sufficient experience and accepting the sample technique of measuring the ears. Spurred on by popular field guides, and even more technical works, that may (e.g., Ingles 1965, Whitaker 1980) or may not (e.g. Palmer 1954, Burt and Grossenheider 1976, Hall 1981, Jameson and Peeters 1988) include ear measurements for both species, observers often attempt to identify these species by such unreliable means as habitat, overall pelage coloration, or the extent and color of spines on the rump, without resorting to measurements.

This identification problem has not been limited to the unsophisticated. We found misidentified animals in all of the museums where we examined specimens, and the same was true of the OCVCD collection (S. G. Bennett pers. comm.). Claims of either species outside of the general ranges described here should be carefully documented, preferably by specimen.

Not surprisingly, the misidentification problem has crept into the scientific literature as well. M'Closkey (1972, 1976) and Meserve (1976) reported on a population of San Diego Pocket Mice in the San Joaquin Hills of Orange County that we have identified as *californicus* (see Results). Their findings on the ecological characteristics of this population have begun to be incorporated in the species specific literature on the San Diego Pocket Mouse (e.g., Zeiner et al. 1990). By calling attention to the potential problem of misidentifying *Chaetodipus* in southern California, we hope to spare others the misfortune we have gone through, and to prevent any further muddying of the literature on these species.

This is but one of several mammal identification challenges confronting biologists in southern California. These problems are especially acute for those, such as consultants, who rarely collect and/or handle specimens. Price et al. (1992) clarified the situation concerning Stephens' Kangaroo Rat (*Dipodomys stephensi*), but other taxa in need of attention include the Brush Rabbit (*Sylvilagus bachmani*), the "Pacific" kangaroo rats (*D. agilis* and *D. simulans*; Sullivan and Best 1997), and the white-footed mice (*Peromyscus,* especially the Brush Mouse *P. boylii*).

Acknowledgments

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of the Orange County Vector Control District shared collection data from Orange County, as well as portions of Los Angeles, Riverside, and San Diego counties. Kris Walden prepared the map. Peter H. Bloom, Scott D. Cameron, J. R. Easton, Karen Kirtland, John N. Ko, Spencer Langdon, and Ruben S. Ramirez, Jr. assisted with data collection in the field. We discussed the status of these species in southern California with Shana C. Dodd, Stephen J. Montgomery, and Mark A. Pavelka; Montgomery also shared *Chaetodipus* photographs with us. David R. Bontrager provided unpublished materials and discussed habitat preferences, much of which could not be incorporated here. Peter L. Meserve's refreshingly honest correspondence was especially appreciated. Bontrager, Daniel A. Guthrie, Montgomery, and an anonymous reviewer made helpful comments on the manuscript.

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Growth and Mortality of the Fantail Sole, *Xystreurys liolepis* (Jordan and Gilbert 1881) off the Western Coast of Baja California, Mexico

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Abstract.—Data on growth and mortality were obtained for fantail sole, *Xystreurys liolepis* collected with otter trawls during 11 cruises off the western coast of Baja California, Mexico, from April 1988 to December 1990. The Bottom temperature varied between 11 to 19°C. In all, 712 *X. liolepis* were caught and over the sampling period the sex ratio of males to females was 1:1.2. Males were smaller than females. The relationship between weight and length is described for males by, $W = 1.1013 \times 10^{-5}\ SL^{3.121544}$ and for females by, $W = 7.6274 \times 10^{-6}\ SL^{3.1932}$. Von Bertalanffy growth parameters were determined to be: $L_\infty = 443$ mm SL, $k = 0.16$, $t_0 = -0.098$ total sample, for males by, $L_\infty = 354.85$ mm SL, $k = 0.151$, $t_0 = -0.918$, and for females by, $L_\infty = 444.68$ mm SL, $k = 0.1636$, $t_0 = -0.423$. The total mortality (Z) rate was 0.62 and the estimated fishing mortality (F) was 0.46. Although fantail sole is not a target species of commercial fisheries, it suffers high mortality as part of the bycatch in the shrimp fishery.

Resumen.—Se obtuvieron datos de crecimiento y mortalidad del lenguado de dos manchas, *Xystreurys liolepis,* éstos fueron colectados con redes de arrastre de fondo durante 11 cruceros, que se llevaron a cabo en la costa occidental de Baja California, México, de abril de 1988 a diciembre de 1990. La temperatura de fondo varió de 11 a 19°C. Se capturaron 712 individuos de *X. liolepis,* y durante el período de muestreo, la proporción de hembras y machos fue de 1:1.2. Los machos presentaron tallas menores comparadas con las de las hembras. La relación peso-longitud esta descrita con la siguiente ecuación para los machos $W = 1.1013 \times 10^{-5}\ SL^{3.121544}$ y para las hembras fue de $W = 7.6274 \times 1.1013 \times 10^{-5}\ SL^{3.121544}\ 7.6274 \times 10^{-6}\ SL^{3.1932}$. Los parámetros de crecimiento de Von Bertalanffy fueron los siguientes $L_\infty = 443$ mm SL, $k = 0.16$, $t_0 = -0.098$ para la muestra total, para los machos fue de $L_\infty = 354.85$ mm SL, $k = 0.151$, $t_0 = -0.918$, y para las hembras por $L_\infty = 444.68$ mm SL, $k = 0.1636$, $t_0 = -0.423$. La tasa de mortalidad total (Z) estimada fue de 0.62 y la mortalidad por pesca fue de 0.46. Aunque al lenguado de dos manchas, no se le considera como una pesquería directa, éste pez sufre una alta mortalidad, debido a la captura incidental como fauna de acompañamiento, en la pesca del camarón.

The fantail sole ranges from Monterey Bay to the Gulf of California at depths from 4 to 79 m (Miller and Lea, 1972). A number of studies on the distribution and abundance of the fantail sole, *Xystreurys liolepis,* have been conducted. Love et al (1986) reported *X. liolepis* in soft sediments off southern California between

6 to 18 m depth. In this area it is most commonly found in shallow offshore waters and its biomass is relatively constant across all open coast depth strata, ranging from 14 to 16 kg (Kramer 1991). However Allen and Herbinson (1991) reported that its standing crop may vary inversely with temperature. Along the western coast of Baja California, Martínez-Muñoz and Ramírez-Cruz (1992) stated that fantail sole is an abundant species, reaching up to 50 cm in length between 24° to 28° north latitude at depths from 13 to 150 m. It was also observed that in summer these fish move into shallow waters to reproduce. Moser and Watson (1990) using CALCOFI samples between 1951 and 1981 mentioned that *X. liolepis* larvae were captured from Punta Concepción to Magdalena Bay, B.C.S and were relatively abundant between the coast of Sebastián Vizcaíno Bay to Magdalena Bay from July to October, reaching peak abundance in August (10 larvae/m^2).

Despite these frequent references to its occurrence, there have been very few studies on the biology of *X. liolepis*. Off California adults of fantail sole feed on polychaetes, shrimp, crabs, and euphasiids. They spawn at the end of winter and the beginning of spring (Frey, 1971).

Although it is not considered a commercially desirable fish, fantail sole has often been found as part of the bycatch in the trawl fishery for shrimp off Baja California and in the Gulf of California (Ramírez-Hernández and Arvizú Matínez 1965). Off the coast of Sinaloa and Baja California *X. liolepis* was caught with shrimp trawls Ramírez-Hernández et al (1965). Castro-Aguirre et al (1970) and van der Heiden (1985) found that fantail sole is frequently caught by shrimp trawlers in the Gulf of California. Pérez-Mellado and Findley (1985) reported 2% of shrimp catches along the Sonora and Sinaloa coasts consisted of *X. liolepis*. Many reach sizes > 30 cm long off the coast of Orange County, California (Mearns 1979).

In Mexico there are no regulations to monitor catching of flattish (Balart 1996), so the numbers reported are reliable. However it is known there is a great fishery for them associated with shrimp trawling with most of the catches sold to California markets.

As Martínez-Muñoz and Ramírez-Cruz (1992) consider this species a potential exploitable flatfish, the purpose of this paper is to provide information on the growth and mortality of *X. liolepis* populations in the Mexican Pacific Ocean, which is needed for the regulation of *X. liolepis* as a fishery resource.

Materials and Methods

Fish were collected from April 1988 to December 1990 from 160 otter trawls conducted during the course of eleven cruises aboard the B/O "EL PUMA" and B/I MARSEP XVI. The 34 sampling stations were located off the western coast of Baja California, from Boca del Carrizal (23°00′ N) to Sebastian Vizcaino Bay (28°51′ N) in depths of 10 and 250 m (Fig. 1). All fish were obtained by an otter trawl that measured 20 m wide and 9 m high at the mouth, 24 m in length, and has a stretched mesh size of 3 cm.

Trawling time and speed were recorded to estimate the area swept by net. The shrimp boat speed was standardized to 2.2 knots while for the "EL PUMA" this was 3 knots. Trawls were towed for 30 minutes along isobaths. Depth was recorded with the Simrad sounder aboard the "EL PUMA", and Furuno sounder

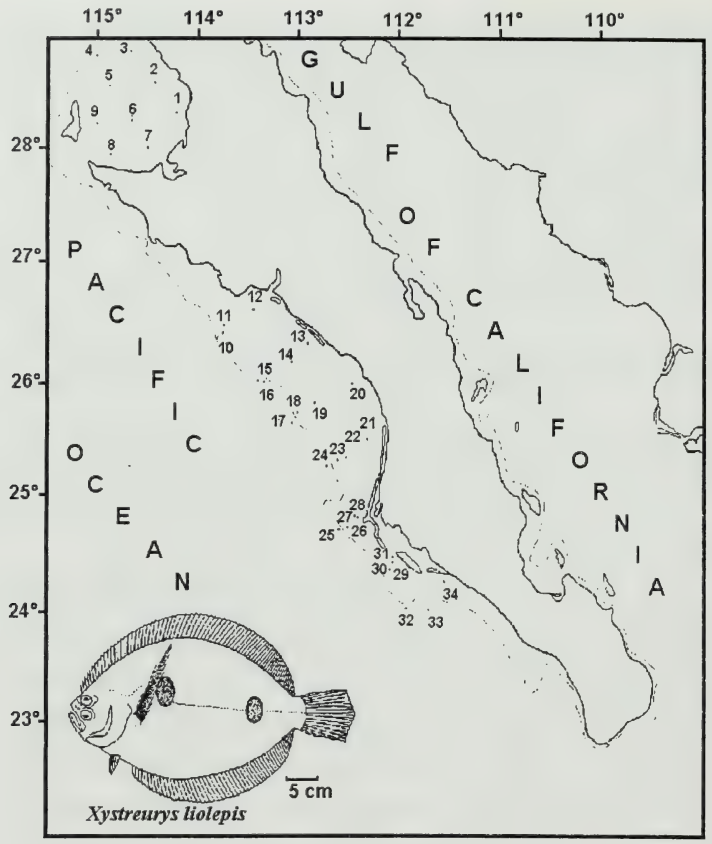

Fig. 1. Stations sampled off Baja California, México, 1988–1990.

on the "MARSEP". Temperature at bottom was recorded with Van Dorn bottles and substrate temperature was directly taken from grab samples.

Specimens of *X. liolepis* were measured (standard length, SL), to the nearest mm, weighed (g) and sexed by eye immediately on recovery. Gonads were examined macroscopically according Nikolskii (1963). These data were used to calculate length-weight relationships varying the logarithmic form of the equation $W = aL^b$ for each sex, where W is weight in grams, a, is the y-intercept, SL is standard length in mm, b: slope using FISAT software (The FAO-ICLARM Stock Assessment Tools; Gayanilo et al. 1994).

Age groups based in length frequency data of *X. liolepis* were estimated using the modal progression method of Petersen (1939). Mean lengths for age groups were fitted with the von Bertalanffy (1938) equation $L_t = L_\infty (1 - \exp^{-k(t-t_0)})$ using the Ford (1933) and Walford (1949) method by FISAT software to describe theoretical growth and growth parameters L_t = standard length of fish at t years, L_∞ = theoretical asymptotic length, k = growth coefficient rate of approach to L_∞, t_0 = theoretical age at which $L_t = 0$. LFDA (Length Frequency Distribution Analysis v. 3.1). Holden and Bravington (1992) and Ortega-Salas (1981, 1988a) basic programs were also used.

Estimation of the instantaneous total mortality rate (Z) was calculated by the

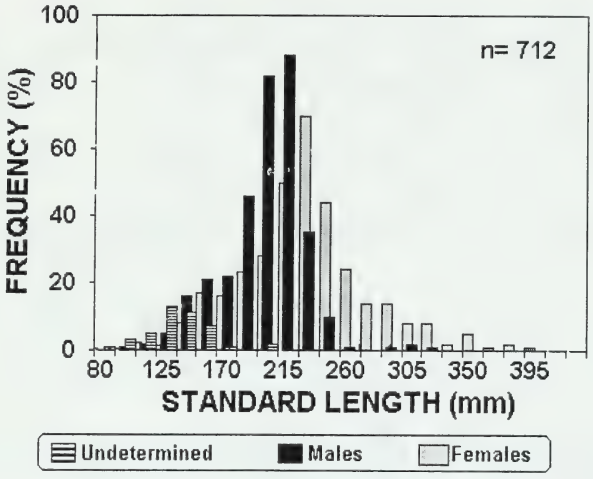

Fig. 2. Length frequency distributions showing population structure of *Xystreurys liolepis* during 1988–1990.

Beverton and Holt (1959) catch curve method described in Ricker (1975) which was based on all fish ≥ 3 years of age. The difference between the instantaneous total mortality coefficient (Z) which includes migration and the natural mortality coefficient (M) gave an estimate of fishing mortality (F): $F = Z - M$. Although *X. liolepis* is considered an exploited species, the natural mortality (M) was estimated as an index from the rate of growth (K) as described by Beverton and Holt (1959).

Results

Fish from all trawls were combined such that 712 fantail sole, ranging in size from 80 to 390 mm and weights from 1.45 to 9 kg were analysed. Of these 338 (47.5%) were females, 331 (46.5%) were males, and the sex of 43 (6.0%) were undetermined. As with most flatfish, females were considerably larger in length and weight relative to males (Fig. 2). The largest female measured 390 mm SL and 1,450 g weighed, compared with 320 mm and 500 g, respectively, for the largest male. The mean values for females were 222.4 mm SL ± 46.44 SD and 277.2 g ± 201.3 SD weight. For males values were 191.6 mm SL ± 30.26 SD and 158.6 g ± 67.74 SD respectively (Table 1).

The ratio of males to females throughout the year was generally 1:1.2 but it varied in winter when the ratio of females was slightly higher. A chi square test showed there was not a significant difference in numbers of females relative to males ($\chi^2 = 0.0732$; d.f. = 1; $P < 0.01$).

Length and weight were closely correlated with the regression coefficients ranging from 0.972 in females to 0.982 in males. The length-weight relationship was determined by non-linear least squares methods (Fig. 3).

Use of a t-test and mean differences showed there was not a significant difference between sexes according to the mean length with 31.19; confidence interval was 95%; d.f. = 669; t = 10.29; significance level = 3.30×10^{-9} at $P < 0.05$,

Table 1.

Sex	n	Minimum	Maximum	Mean	St. dev.
Males	331				
Standard length (mm)		93.0	320.0	191.64	30.26
Weight (g)		15.5	500.0	158.64	67.74
Females	338				
Standard length (mm)		100.0	390.0	222.38	46.44
Weight (g)		17.2	1450.0	277.21	201.3
Undetermined	43				
Standard length (mm)		80.0	197.0	127.26	24.59
Weight (g)		9.1	210.0	45.15	38.35

even with mean weight there was not significant differences between sexes with 115.87; 95%; d.f. = 669; t = 10.43; sig. level = 3.97×10^{-9}.

The von Bertalanffy equations describing theoretical growth of males and females of the fantail sole are shown in Fig. 4. After age 3 (210 mm), females were consistently longer and heavier than males due to differences in reproductive condition or general robustness of fish, although the rate of growth (K) for the two sexes was similar (Fig. 5). However females attained an older age and longer length than males.

For the estimation of mortality rates the best results were obtained by the Beverton and Holt (1959) method (Z = 0.62; M = 0.16; F = 0.46) (Fig. 6). Although these populations of *X. liolepis* are considered exploited, the natural mortality coefficient (M) was taken as the (K) value, as an index, obtained from the von Bertalanffy growth equation (Beverton and Holt 1959). These results suggest that even though fantail sole is not a target species in the commercial fishery, the rate of fishing mortality is higher than natural mortality, possibly due to the large bycatch of flatfish, including fantail sole, in the shrimp fishery. Chavez and Ramos-Padilla (1974) mentioned that along the western coast of Baja California between 25 and 100 m depth that of 75.5 tons caught 3.5 tons were brown

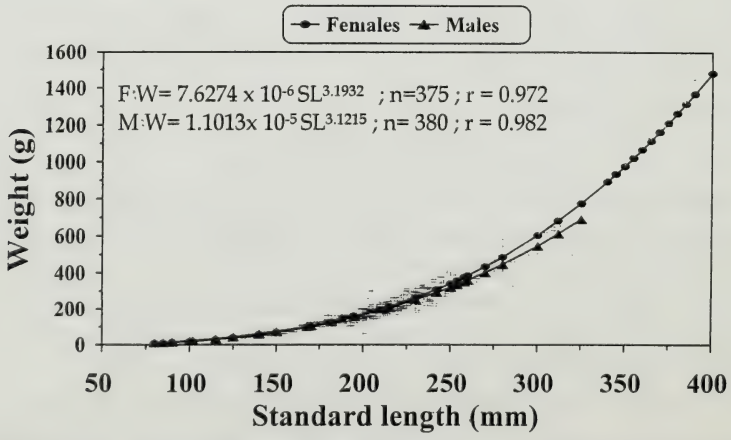

Fig. 3. Length-weight relationships of male and female *Xystreurys liolepis* from Baja California.

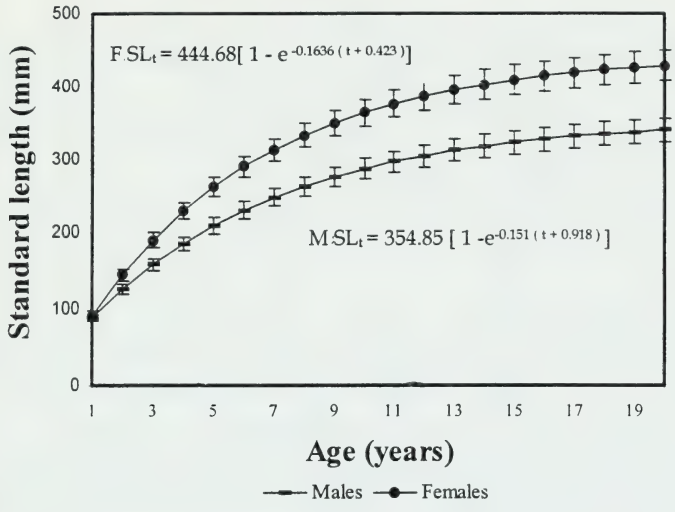

Fig. 4. Growth curve of female and male *Xystreurys liolepis* in standard length, showing standard dispersion error at 95% confidence.

shrimp, *Penaeus californiensis,* shark, flatfish, an other fish and 72 tons were considered rubbish such as red crab (*Pleuroncodes planipes*).

Discussion

There have been few previous studies concerned with the biology of *X. liolepis* so the growth and mortality parameters estimated here can only be compared with those obtained in studies of other species of flatfish (Table 2 and 3).

In comparison with many other flatfish species for which growth data are avail-

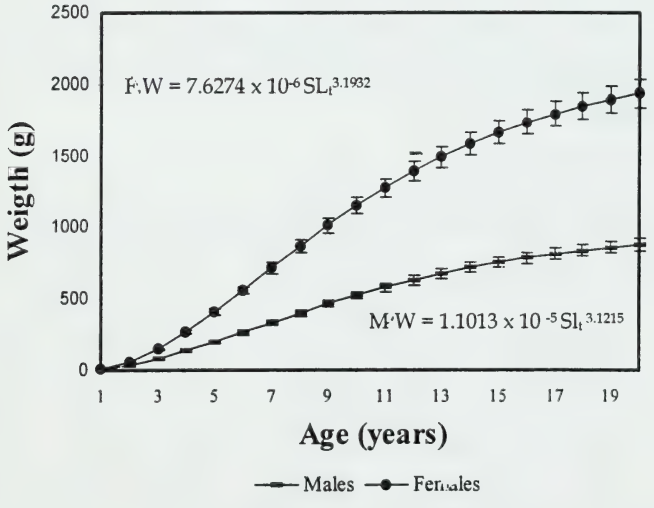

Fig. 5. Weight curve of female and male *Xystreurys liolepis* in weight, showing the standard dispersion error at 95% confidence.

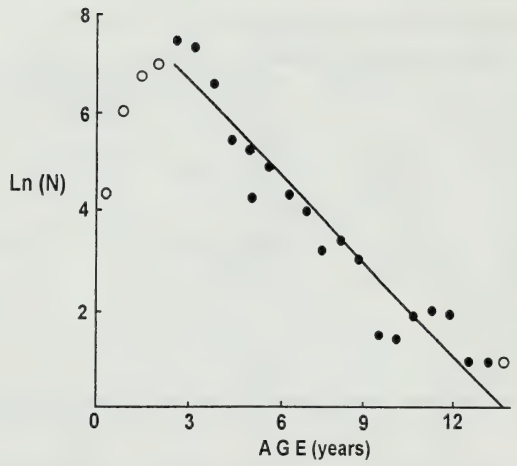

Fig. 6. Catch curve for fantail sole (*Xystreurys liolepis*) caught off Baja California, Mexico, (N = 712). The curve is slightly non-linear but regression analysis suggests a value of Z = 0.62. Open symbols indicate values not included in the regression.

able, the rate of growth of *X. liolepis* is comparatively high and the species attains a size large enough for commercial exploitation at 3 years age.

The ratio of the sexes in all species was generally 1:1. The females are also larger than males and have a higher rate of growth.

According to Dagang et al. (1992) as cited in Liu (1990), flatfish generally have a life span of up to 5–6 years, while the oldest fish are occasionally more than 10 years old. At most *X. liolepis* attains an age of 13 years. The age compositions for both sexes of the same stock are clearly different and males generally have a shorter life span than females. Thus, while males dominate the younger age-groups, females are more abundant in the older groups.

Off the western coast of Baja California, a high fishing mortality of flatfish, including *X. liolepis,* occurs resulting from intensive trawl fishing for shrimp according to Ramírez-Hernández and Arvizú Matínez (1965); Ramos-Padilla (1974); Ramírez-Hernández et al. (1965); Castro-Aguirre et al. (1970) and van der Heiden (1985).

Table 2.

Specie	Location	Sex	L_∞ (mm)	k	t_0	Source
Hippoglossina stomata	*Baja California México.*		*208.09 SL*	*0.1843*	*0.2096*	*Ramirez Murillo (1995)*
Xystreurys rasile	Mar del Plata, Argentina.		372.7	0.43	−0.169	Fabre and Cousseau (1988)
Eopsetta grigorijewi	Sea Yelow, China.	Male	342.47	0.23	−0.184	Dagang *et al.,* (1992) as cited by Liu (1990)
		Fem.	342.57	0.3	−1.02	
Limanda limanda	Isle of Man, UK.	Male	221.52	0.604	0.4254	Ortega-Salas (1981, 1988a, b)
		Fem.	329.73	0.3178	0.2394	
Xystreurys liolepis	Baja California, México.	Male	354.85 SL	0.918	−0.151	Present Paper
		Fem.	444.68 SL	0.163	−0.918	

Table 3.

Specie	Location	Z	Source
Hypsopsetta guttulata	*Anaheim Bay, USA*	*2.6*	*Lane (1975)*
Limanda limanda	*Isle of Man, UK*		*Ortega-Salas (1981, 1988 a and b)*
Female		*1.06*	
Male		*1.39*	
Xystreurys liolepis	Baja California, México	0.62	Present paper

This paper shows that females (L_∞ = 444.68 mm SL) grow bigger than males (L_∞ = 354.85 mm SL) and the total mortality rate was 0.62 of which fishing mortality was 0.46. Although *X. liolepis* is not a target species of commercial fisheries, the rate of fishing mortality is higher than natural mortality, possibly due to the large bycatch of flatfish, including fantail sole, in the shrimp fishery. It is considered a potential exploitable flatfish but needs to have regulations as a fishery resource.

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The Euryhaline Gobiid Fish, *Gillichthys mirabilis* Cooper 1864, Second Intermediate Host of the Trematode, *Pygiopsoides spindalis* Martin 1951

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Abstract.—Pygidiopsoides spindalis Martin 1951 is reported from the gills of a new second intermediate host, *Gillichthys mirabilis* Cooper 1864 (the longjaw mudsucker), collected at Point Mugu Lagoon, (Naval Air Weapons Station), Point Mugu, California. *Ascocotyle* (*Phagicola*) *diminuta* Stunkard and Haviland 1924 were also found. Metacercariae were enzymatically excysted from gills and examined by scanning electron microscopy. *Fundulus parvipinnis* Girard were examined and yielded *P. spindalis* and *Ascocotyle sexidigita* Martin and Steele 1970. Parasites reported from the longjaw mudsucker were reviewed. The presence of these trematodes in spite of heavy contamination may be indicative of the health of the Mugu lagoon ecosystem.

Martin (1951) described *Pygidiopsoides spindalis,* a heterophyid trematode, from naturally infected *Fundulus parvipinnis* Girard collected at Newport Bay, CA, but did not describe the infection site in the killifish. Martin further elucidated the life cycle of *P. spindalis* (Martin 1964) by exposing *F. parvipinnis* to cercariae shed from naturally infected *Cerithidea californica* Haldeman, and determined that the cercaria "works its way to the bony support of the [fish] gill before encysting". The trematode was not described from other killifish organs nor was the naturally occuring definitive host for *P. spindalis* described.

Earlier, Martin described *Euhaplorchis californiensis* (1950a) from the brain of *F. parvipinnis* collected at Playa del Rey, CA, indicating that "Another fish, *Gillichthys mirabilis* Cooper 1864, commonly called the 'mudsucker,' having similar opportunities for infestation, was not parasitized by this trematode . . .". No other parasites of *G. mirabilis* were mentioned. *Gillichthys mirabilis* was reported, however, as a successful experimental second intermediate host for another new trematode, *Stictodora hancocki,* described by Martin (1950b, as *Parastictodora*) which encysted in "the tissues of the lower jaw, around the eyes . . ." and elsewhere. I have observed many such naturally occuring metacercarial cysts on mudsuckers collected in the course of this study.

Gillichthys mirabilis has been the subject of many studies, several of which have focused on the gill arches and gill filaments, but little mention of gill parasites has been made. Barlow (1963) briefly discussed the parasites of *G. mirabilis* noting that, "The Salton Sea [variety of these] fish at times are heavily infested with a monogenetic trematode, but so are coastal populations." Todd and Ebeling (1966) studied aerial respiration in the mudsucker, and even sectioned the buccal roof of that and the killifish, but did not discuss gill parasites, although this may have significantly impacted their study. Martin and Multani (1970) reported mono-

genetic trematode metacercaria in mud suckers from Baja, California, Seal Beach, and Newport Bay. Love and Moser (1983) presented a listing of heterophyids for *G. mirabilis* on the West Coast, but did not include *P. spindalis.* Armitage (1997) looked at several *G. mirabilis* collected at the Twelfth Street bridge at Mugu, but no metacercariae were found. No other report has been made for other second intermediate hosts for *P. spindalis,* natural or experimental in California. In this paper, a new, naturally occuring second intermediate host, the longjaw mudsucker, is reported for *P. spindalis.*

Materials and Methods

Twenty *G. mirabilis* were collected by trap from the Laguna Road bridge over the western Mugu lagoon area of the Point Mugu Naval Air Weapons Station, CA, from January 1998 through May 1998. Twenty seven *F. parvipinnis* were also collected. The gills, intestines and livers of these fish were separately harvested and examined under a dissecting microscope for the presence of metacercarial cysts. Hearts were not examined. Experimental definitive hosts were not employed. Over 200 of each of the trematodes in this study were successfully excysted. Excysted live worms were fixed in hot formalin and infected gills were fixed in glutaraldehyde. Dehydrated worms were sputter coated at 30mA for 4 minutes and plastic gill sections were stained in Fuchsin and coverslipped. Photomicrographs were taken of whole live material under cover slip pressure, of sections and of fixed worms on a compound microscope and on a scanning electron microscope. Anatomical measurements were not made.

Results and Discussion

Twenty *G. mirabilis* were collected and only 4 lacked cysts in the gills, which averaged 8 cysts per filament when infected. Most had cysts of varying sizes, indicating that infections possibly continued occuring over time. Additionally, *Ascocotyle* (*Phagicola*) *diminuta* Stunkard and Haviland 1924 metacercariae were excysted from the mudsucker gills at the same time as *P. spindalis,* representing a new host record for this trematode as well. These worms exhibited the same anterior row of 16 oral spines with a 2nd row of 2 accessory dorsal spines (Fig. 1A) as described from *Leptocottus armatus* Girard 1854 collected at Mugu (Armitage 1997). Love and Moser (1983) reported the presence of *A. angrense* Travassos 1916 from *G. mirabilis* in Southern California, based on an unpublished personal communication with Baker, however, none of the ascocotylid specimens excysted in this or the previous study (Armitage 1997) exhibited over 16 spines in the anterior row, therefore, it is quite possible that Baker, as well as Yoshino (1972) were looking at *A.* (*P.*) *diminuta,* and not *A. angrense.*

All *F. parvipinnis* specimens examined contained *P. spindalis* in their gills (Fig. 1, B, E, F). *Ascocotyle sexidigita* Martin and Steele 1970 (Fig. 1C–D) were excysted from the intestines of *F. parvipinnis* as reported by Martin and Steele (1970). No cysts were found in or along the intestines or livers of the mudsuckers collected at the same time as the killifish, although *A. sexidigita* was reported from the mudsucker intestine by Martin and Multani (1970).

The area chosen for collection, along Laguna Road, bisecting the lagoon, is marked as contaminated by pesticides. The California Toxic Substances Monitoring program has shown that the fish in Mugu lagoon contain "among the highest

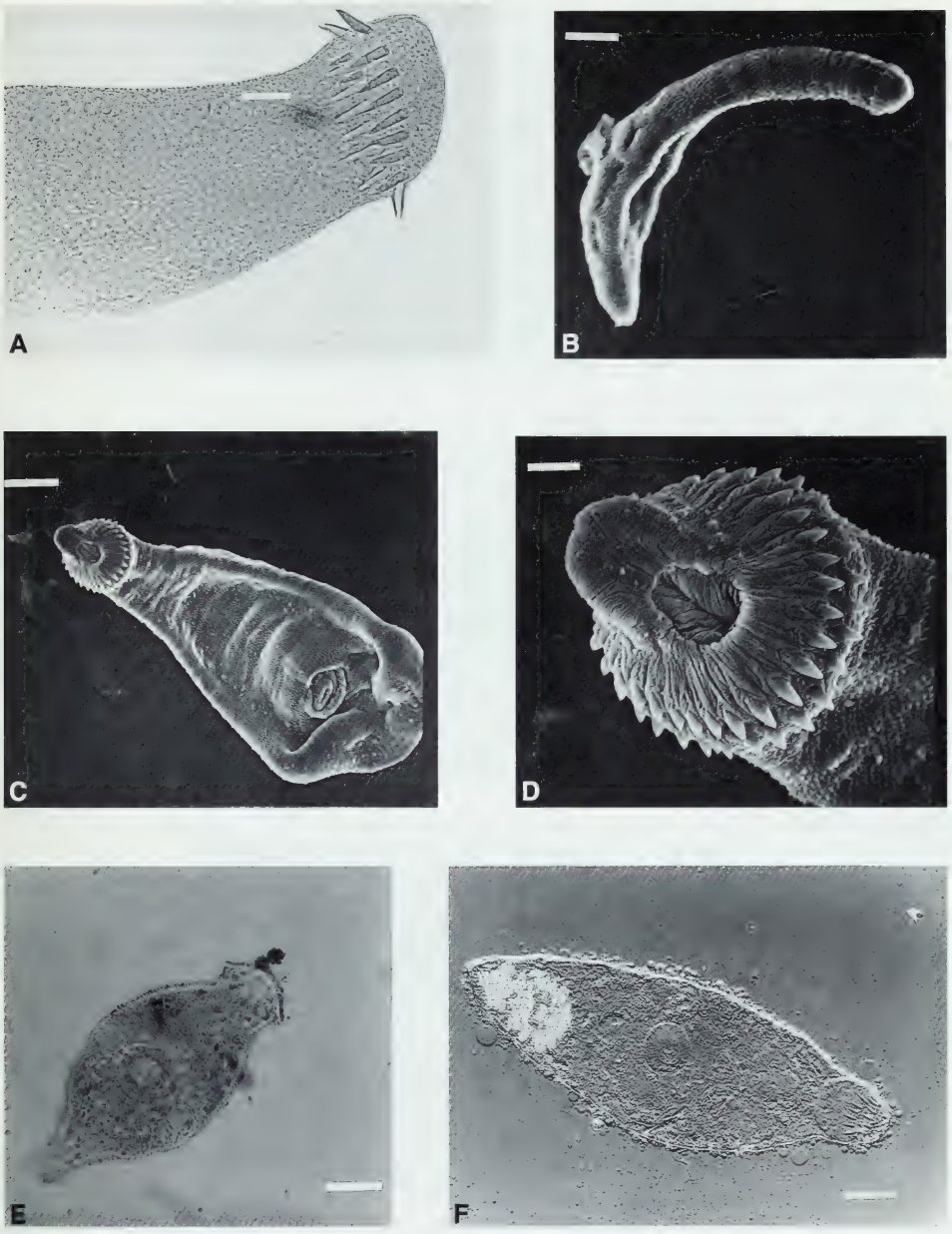

Fig. 1. A. *A. (P.) diminuta* excysted metacercaria from *G. mirabilis* scale bar = 10 micrometers. B. *P. spindalis* excysted metacercaria from *G. mirabilis* scale bar = 30 micrometers. C. *A. sexidigita* excysted metacercaria from *F. parvipinnis* scale bar = 70 micrometers. D. *A. sexidigita* excysted metacercaria from *F. parvipinnis* scale bar = 20 micrometers. E. W.M., *P. spindalis* excysted metacercaria from *G. mirabilis,* scale bar = 35 micrometers. F. W.M., *P. spindalis* excysted metacercaria from *G. mirabilis,* scale bar = 35 micrometers.

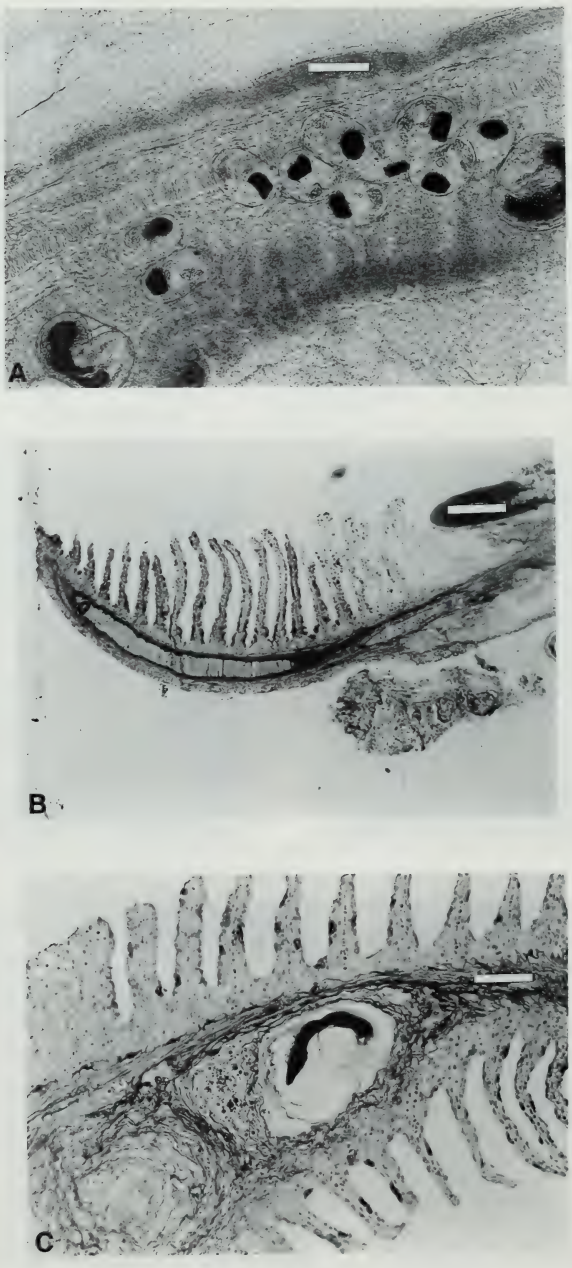

Fig 2. A. *P. spindalis* in *G. mirabilis* gill W.M. scale bar = 100 micrometers. B. Sectioned *G. mirabilis* gill, uninfected. scale bar = 70 micrometers. C. Sectioned *G. mirabilis* gill, infected scale bar = 40 micrometers.

concentrations of arsenic, silver, DDT, and methoxychlor measured in California" (Saiki 1994), yet the abundant presence of this and other trematode parasites indicates that all of the requirements for it to complete its complex life cycle are in place and well established. This could mean that in spite of the contamination, the health of the ecosystem is such that large numbers of cercaria are being

produced by snails, and that piscivorous birds and mammals frequent the lagoon to feed. Like *A. (P.) diminuta, P. spindalis* requires a snail (probably *C. californica* (Martin 1964)) as the first intermediate host, and a bird or mammal as the definitive host. Further work must be done to identify naturally occuring definitive hosts of these trematodes at the Mugu lagoon.

Acknowledgements

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First Fossil Record of the Pteropod *Limacina* from the Pacific Coast of North America

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Abstract.—Pteropods from upper Eocene to lower Miocene deep-marine rocks in western Washington represent the first fossil record of genus *Limacina* from the Pacific coast of North America and the northernmost fossil occurrence in North America for this genus. Two species were found. Both occur in concretions in siltstone, and one was also found in limestone formed by chemosynthetic processes. Both species closely resemble other late Eocene to early Miocene *Limacina* spp. from Europe, Australia, and New Zealand, but poor preservation of the Washington specimens prevents their identification to the species level.

Pteropods are a group of rather poorly known free-swimming, holoplanktonic gastropods. Generally, they are found only in very restricted numbers. Their shells are thin, very fragile (Janssen 1990a), and consist of aragonite, which is easily subject to dissolution (Hodgkinson et al. 1992; Janssen 1991). Limacinids are euthecosomatous pteropods with a small (1–5 mm in height), sinistrally (left-handed) coiled shell.

Living species of *Limacina* are found in all the world's oceans (Tesch 1946, 1948; McGowan 1968; Bé and Gilmer 1977). Most of these species have a free-swimming veliger stage that hatches from a free-floating egg mass, although some species have developed brood protection through the early or entire larval stage (Bandel et al. 1984). The planktonic mode of life of pteropods can allow for wide geographic distribution, and there are indications that fossil species can be used successfully for long-distance correlations (Janssen 1990a).

The oldest known pteropods are Paleocene in age, but only two species are known. One is *Limacina mercinensis* (Watelet and Lefèvre 1885), and its earliest occurrence is latest Paleocene (Janssen and King 1988; Janssen 1991). It has been reported from Paleocene rocks of Alabama (Tracey et al. 1993), England, and Denmark (Janssen and King 1988). The other species is *Limacina advenulata* (Darragh 1997), from Victoria, Australia. Whether this species is of early or late Paleocene age has not been determined.

Other fossil species of *Limacina* have been reported from Eocene rocks of the southeastern United States (see Hodgkinson et al. 1992 for a modern summary), England and France (Curry 1965, 1981), the Ukraine (Korobkov 1966; Bielokrys 1997), and New Zealand (Maxwell 1992); Eocene/Oligocene rocks of Mississippi (MacNeil and Dockery 1984; Dockery and Zumwalt 1986), Germany (Koenen

1892), and Australia (Janssen 1989a); Oligocene rocks of Denmark (Janssen 1990b); Oligocene/Miocene rocks of the North Sea (Janssen 1989b) and Australia (Janssen 1989a); Miocene of Poland (Janssen and Zorn 1993), other areas in Europe (see Janssen 1984 for a modern summary), Mexico, and the Dominican Republic (Collins 1934); Pliocene rocks of Japan (Ujihara 1996); and Jamaica (Janssen 1998).

The fossil record indicates that *Limacina* was confined to warm waters and had widespread geographic dispersal during the Eocene and early to middle Miocene. The dispersal of this genus to present-day, worldwide distribution (tropical to arctic and antarctic waters) took place relatively recently, probably during the Pleistocene and possibly during the Pliocene. Several modern species of *Limacina* are cosmopolitan (Bernasconi and Robba 1982).

There are few reports of Tertiary pteropods from the Pacific coast of North America (Collins 1934). The only detailed account is by Squires (1989), who reported three species in two genera, *Praehyalocylis* and *Clio,* from upper Eocene to middle Miocene rocks in Oregon and Washington. Specimens representing a third genus, *Limacina,* are the subject of the present investigation. They are of latest Eocene to early Miocene in age and represent the first known fossil record of genus *Limacina* from the Pacific coast of North America and the northernmost fossil occurrence in North America for this genus. Today, there are five species of *Limacina* found in the northeastern Pacific Ocean, and their geographic distributions are given by McGowan (1968). Only one of these species, *Limacina helicina* (Phipps), is found primarily north of Point Conception, California. The other species are found in southern California and/or Baja California, Mexico.

The pteropod specimens described here, as well as the associated fauna, are reposited in the Natural History Museum of Los Angeles County, Invertebrate Paleontology Section (abbreviated LACMIP).

Systematic Paleontology

Class Gastropoda Cuvier, 1797

Order Thecosomata Blainville, 1824

Suborder Euthecosomata Meisenheimer, 1905

Family Limacinidae Gray, 1847 [=Spiratellidae Dall, 1921]

Genus *Limacina* Bosc, 1817

Type species.—*Clio helicina* Phipps, 1774, by monotypy; Recent, polar seas, North Atlantic, and Pacific coast of North America.

Remarks.—There has been considerable inconsistency and confusion in the literature regarding the proper generic name to use for this group of pteropods. As reported by Janssen (1989a) and Janssen and Zorn (1993), biologists usually use the name *Limacina,* but paleontologists commonly use the name *Spiratella* Blainville 1817. Both genera were named in the same month (December) of 1817, and both have the same type species. Curry (1981) reported that the name *Spiratella* was registered in the archives of the "Bibliothèque Nationale de Paris" before the name *Limacina* was registered, and some workers (e.g., Curry 1981; Maxwell 1992) have argued that the name *Spiratella* should be used in preference to the name *Limacina.* There has not been uniform acceptance of this informal conclusion (e.g., Janssen 1989a; Ujihara 1996), and it is apparent that an application to the International Commission on Zoological Nomenclature (abbreviated

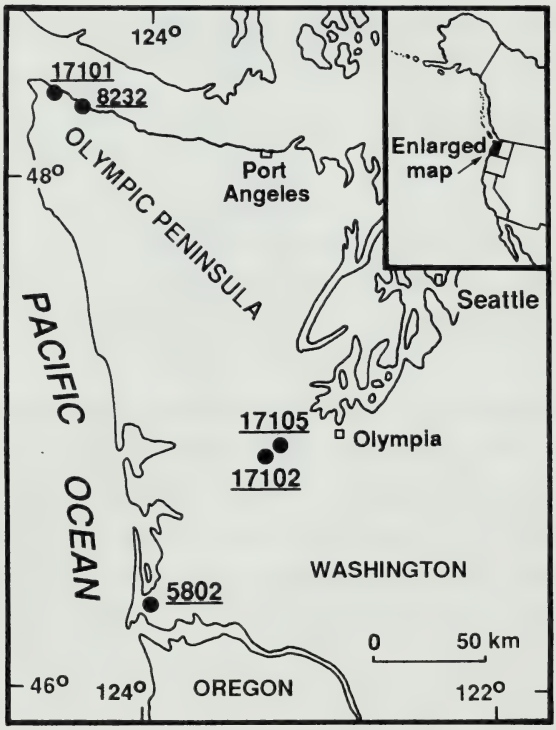


Fig. 1. Index map to LACMIP localities where fossil *Limacina* spp. have been found in Washington.

ICZN) is necessary for a formal decision of name priority. To date, no application has been made, but one will be made in the near future by A. W. Janssen (pers. comm.). Pending the ICZN decision, we have subjectively decided, like Bé and Gilmer (1977) and Janssen (1989a), to use the name *Limacina* because it is more frequently used than *Spiratella.* In addition, usage of the name *Limacina* will help bring the work of paleontologists and biologists in line.

Adding to the confusion around the synonymous taxa *Limacina* and *Spiratella,* in older papers (e.g., Kittl 1886) the name *Spirialis* Eydoux and Souleyet 1840 has been used (at least, in part) for this same group of pteropods. For a full synonymy of genus *Limacina,* see Spoel (1967:36).

Traditionally, *Limacina* is the only genus recognized within this family. Attempts to split the genus into three subgenera have not received wide acceptance because the boundaries between the subgenera are unclear (Bielokrys 1997) and the fossil forms were not fully treated (Janssen 1989a).

Limacina is characterized by a sinistrally coiled shell (anatomically dextral) that can be conispiral (the term "trochoid" is used by some authors) or more flattened and involute. Characters such as relative whorl height, aperture outline or aperture elongation, and development of the umbilicus are quite variable and can coincide in different species (Bielokrys 1997). In order to differentiate species, it is critical to have the entire adult teleoconch preserved.

Limacina sp. 1
Figures 2–5

Description.—Shell very small (height 0.7 to 0.83 mm), smooth, sinistral, with up to five whorls, rather quickly increasing in diameter; shell is 1.7 times wider than high. Apical side of the body whorl flat, with the spire barely protruding. Protoconch smooth. Aperture oval, slightly opisthocline, periphery seemingly evenly rounded; outer lip broken but apparently with a slight flare. Umbilicus about 20 percent of shell diameter. Large specimens with faint axial and spiral threads on body whorl.

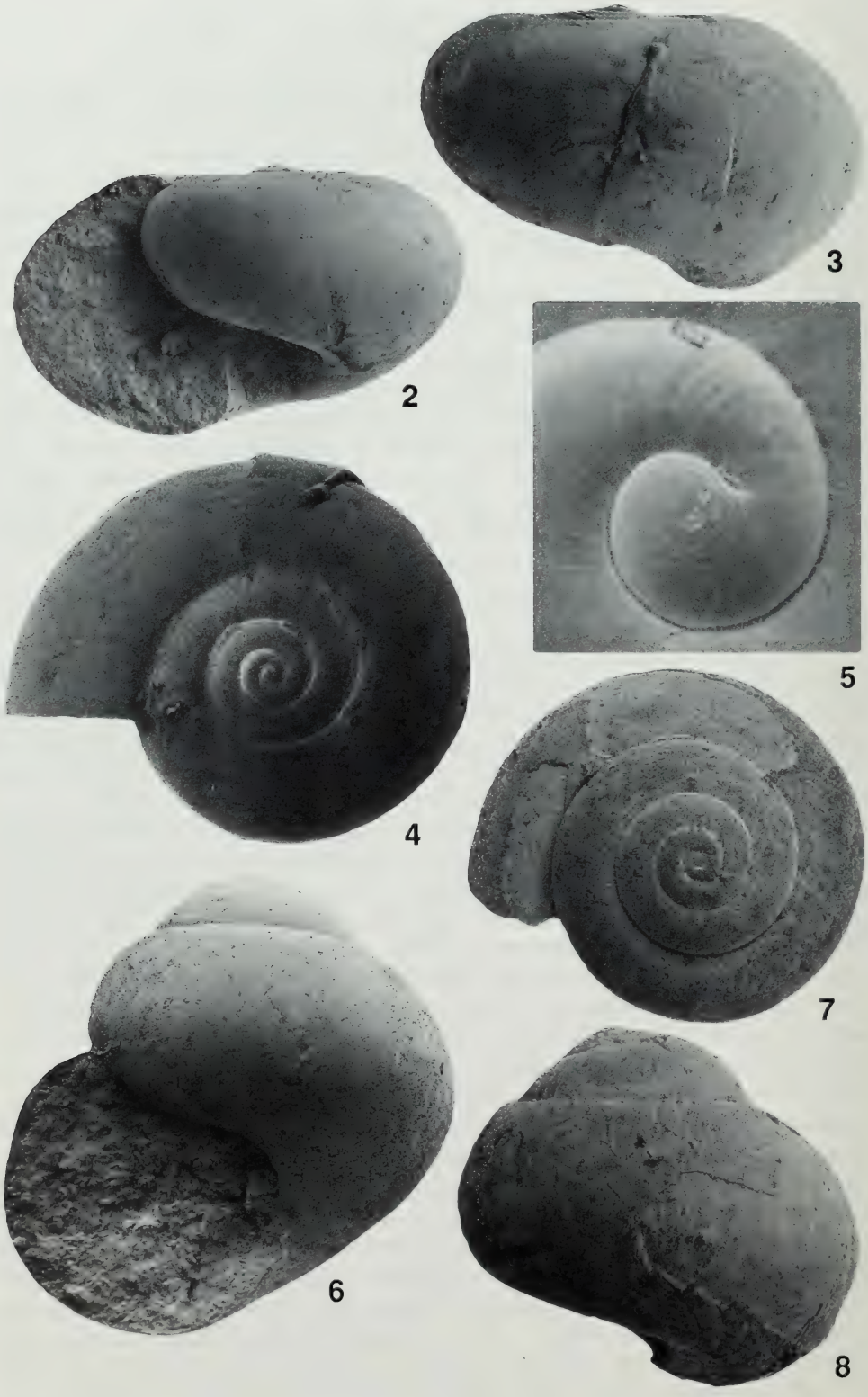
Remarks.—More complete specimens of *Limacina* sp. 1 are needed before a species identification can be made. In terms of the nearly flattened spire, shape of the body whorl, and relative width of the umbilicus, *Limacina* sp. 1 is very similar to *Limacina atypica* (Laws 1944; Janssen 1989a:7–8, pl. 1, figs. 1–2; pl. 10, figs. 1–3) from ?upper Oligocene to lower Miocene rocks in Australia and from Miocene rocks in New Zealand. *Limacina* sp. 1 differs from *L. atypica* by having a slightly wider umbilicus (20 percent of the shell diameter rather than 15 percent). In addition, although the apertural periphery is not completely preserved on *Limacina* sp. 1, the specimens seem to differ from *L. atypica* by having a rounded anterior part of the aperture rather than a projected anterior part.

Material.—Thirty-five specimens, including hypotypes LACMIP 12722 and 12723.

Age.—Latest Eocene to early Miocene.

Stratigraphic occurrence.—Three specimens of *Limacina* sp. 1 were found in limestone at LACMIP loc. 5802 (Bear River deposit). The limestone, which is late Eocene in age and temporally equivalent to the lower part of the Lincoln Creek Formation (Squires and Goedert 1991), is rich in mollusks and formed in a deep-marine chemosynthetic environment (Goedert and Squires 1990).

Limacina sp. 1 was found in two concretions at LACMIP loc. 17102. One of the concretions contained the following: 24 specimens of *Limacina* sp. 1, a few internal molds of an unidentifiable triangular-shaped pteropod, some specimens of minute gastropods (including the opisthobranchs *Tornatellaea*? sp. and *Scaphander*? sp.), the bivalve *Delectopecten* sp., minute bivalves, a cheliped of the crab *Portunites triangulum* Rathbun, fish scales, and carbonized-wood fragments. The other concretion contained a single specimen of *Limacina* sp. 1 and a specimen of the nautiloid *Aturia angustata* (Conrad). In the gray siltstone surrounding the concretions, specimens of the gastropod *Turritella oregonensis* (Conrad), the turrid gastropod *Spirotropsis*? sp., *Delectopecten* sp., the bivalve *Cyclocardia* sp., *Aturia angustata,* and *Portunites triangulum* were moderately common. *Turritella oregonensis* ranges from early to middle Miocene (Addicott 1976). *Portunites triangulum* ranges from latest Eocene to latest Oligocene or early Miocene, but it is most common in rocks of late Eocene to early Oligocene age (R. Berglund person. commun.). *Aturia angustata* ranges from latest Eocene to early Miocene (Armentrout 1973). Based on the overlapping ranges of these three species, the rocks at locality 17102 are of early Miocene age. Locality 17102 plots in the Lincoln Creek Formation on the geologic map of Pease and Hoover (1957). This formation ranges in age from late Eocene to early Miocene (Moore 1984), and the rocks at locality 17102 are assignable to the upper part of the formation.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The association at locality 17102 of pteropods, other small gastropods, small bivalves (including the "mud pecten" *Delectopecten*), crab remains, fish scales, and carbonized wood is very similar to other pteropod-bearing bathyal (greater than 200 m depth) assemblages found elsewhere in Tertiary formations of Washington and Oregon. These other bathyal assemblages commonly are a mixture of faunal remains derived from pelagic communities (pteropods, fish scales) and from nearby nonmarine communities (wood) (Squires 1989). The nautiloid at locality 17102 is a pelagic component, and the *Turritella* specimens probably represent a shallow-marine component that underwent post-mortem transport by turbidity currents.

Five specimens of *Limacina* sp. 1 were found in a concretion in the Lincoln Creek Formation at LACMIP locality 17105, which is stratigraphically and paleoenvironmentally equal to locality 17102. Also in the concretion were some specimens of the scaphopod *Fustiaria*? sp., a few unidentified turrids, *Delectopecten* sp., and a crab fragment.

A single specimen of *Limacina* sp. 1 was found in a concretion at LACMIP locality 8232, and the concretion also contained a specimen of the scaphopod *Dentalium* sp., minute bivalves, and wood fragments. This locality is in the lower Oligocene undifferentiated part of the Makah Formation, and this part of the formation, like the rest of the Makah Formation, was deposited in a predominantly lower to middle bathyal environment (Snavely et al. 1980).

A single specimen of *Limacina* sp. 1 was found in deep-marine rocks in the lower Oligocene Jansen Creek Member of the Makah Formation at LACMIP loc. 17101, in association with *Limacina* sp. 2.

Limacina sp. 2
Figures 6–8

Description.—Shell minute (up to 5 mm in height), conispiral (naticiform), slightly higher than wide, sinistral, 4 to 5 whorls, spire low to moderately low; shell smooth except for regularly spaced sinuous, shallow axial grooves (growth lines?); suture moderately impressed, protoconch smooth. Aperture large, outer lip mostly incomplete, columella missing. Umbilicus area mostly missing, apparently narrow.

Remarks.—More complete specimens of *Limacina* sp. 2 are needed before a species identification can be made. In terms of the relatively low spire, subglobose body whorl, relative height of the aperture versus the height and width of the body whorl, and the apparently very narrow umbilicus, *Limacina* sp. 2 has the most similarity to some specimens of *Limacina pygmaea* (Lamarck 1804:30; Watelet and Lefèvre 1885:101, pl. 5, figs. 3a–c; Curry 1965:362, figs. 18a, 18b, 19;

←

Figs. 2–8. SEM micrographs of fossil *Limacina* spp. from Washington; 2–5, *Limacina* sp. 1, LACMIP loc. 17102, lower Miocene part of the Lincoln Creek Formation, Washington; 2–4, hypotype LACMIP 12722, ×50, height 0.83 mm; 2, apertural view; 3, abapertural view; 4, apical view; 5, hypotype LACMIP 12723, ×500, maximum diagonal distance 0.14 mm, apical view showing protoconch; 6–8, *Limacina* sp. 2, LACMIP loc. 17101, lower Oligocene Jansen Creek Member of the Makah Formation, Washington; 6–7, hypotype LACMIP 12724, ×35, height 1.9 mm; 6, apertural view; 7, apical view; 8, hypotype LACMIP 12725, abapertural view, ×34, height 1.6 mm.

Curry 1981:37, pl. 1, figs. 3a, 3b; Hodgkinson et al. 1992:19, pl. 3, figs. 14, 15) from middle Eocene (Lutetian Stage) rocks of Paris Basin, France, England, and Texas. *Limacina pygmaea* has considerable morphologic variation in the relative spire height, from flush to nearly half of the height of the shell. Because of this variation, some authors have recognized subspecies of *L. pygmaea. Limacina pygmaea bernayi* (Laubrière 1881:377, pl. 8, fig. 5; Cossmann and Pissarro 1910–1913:pl. 60, figs. 1–2 of the pteropods) from middle Eocene (Lutetian Stage) rocks of France is one of these subspecies, and it has a relatively low spire and can have axial grooves. In these two features, it is closely similar to the specimens of *Limacina* sp. 2.

Limacina sp. 2 also has some close similarity to *Limacina nemoris* (Curry 1965: 362, figs. 16a–b; Curry 1981:37, pl. 1, figs. 5a, b; Hodgkinson et al. 1991:18, pl. 3, figs. 9, 10) from the middle Eocene upper Bracklesham Beds of southern England, the upper Eocene "marnes bleues" of France, the upper Eocene Stone City and Cook Mountain formations of eastern Texas, and the upper Eocene Lisbon Formation of Alabama. *Limacina* sp. 2 does not have the inclined suture that can be present on some specimens of *L. nemoris.*

Material.—Twelve specimens, including hypotypes LACMIP 12724 and 12725.

Age.—Early Oligocene.

Stratigraphic occurrence.—The specimens were found in a concretion at LACMIP locality 17101, and they were in the matrix that surrounded fragments of a small squat crab (*Munida*? sp., R. Berglund pers. comm.). This locality is in the lower Oligocene Jansen Creek Member of the Makah Formation, and this member represents a transported olistostromal rock unit containing mostly shallow-water marine conglomerate and fossiliferous sandstone enclosed in deep-water (1,000 to 2,000 m) marine siltstone and sandstone (Snavely et al. 1980; Squires and Goedert 1994).

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Appendix

Localities

LACMIP 5802. "Bear River deposit". In an abandoned quarry on the south side of Bear River in the SE ¼, SE ¼ of section 20, T. 10 N, R. 10 W, U.S. Geological Survey 15-minute Chinook Quadrangle, 1949 (photorevised 1984), Pacific County, Washington. Strata temporally equivalent to the lower part of the Lincoln Creek Formation. Collectors: J. L. and G. H. Goedert, May 30, 1998.

LACMIP 8232. Float from beach terrace exposures approximately 2000 m northwest of the mouth of the Sekiu River, near center of SW ¼ NW ¼ sec. 5, T. 32 N, R. 13 W, U.S. Geological Survey 7.5-minute Sekiu River Quadrangle, 1984 (provisional edition), south shore of Strait of Juan de Fuca, Clallam County, Washington. Lower Oligocene part of the Makah Formation. Collector: J. L. Goedert, April 30, 1998.

LACMIP 17101. Approximately 320 m northwest of the mouth of Jansen Creek, near center of sec.

26, T. 33 N, R. 14 W, U.S. Geological Survey 7.5-minute Sekiu River Quadrangle, 1984 (provisional edition), south shore of Strait of Juan de Fuca, Clallam County, Washington. Lower Oligocene, Jansen Creek Member of the Makah Formation. Collector: J. L. Goedert, March, 1997.

LACMIP 17102. Siltstone 2 m below a hardground with reworked concretions, on the east side of a logging road, approximately 360 m north and 230 m west of the southwest corner of sec. 31, T. 17 N, R. 6 W, U.S. Geological Survey 7.5-minute South Elma Quadrangle, 1986 (provisional edition, minor revisions 1993), Grays Harbor County, Washington. Lower Miocene part of the Lincoln Creek Formation. Collectors: J. L. Goedert, G. H. Goedert, and E. Z. Nordlander, Spring, 1998.

LACMIP 17105. Concretion 1 m below a 4 cm-thick hardground (with reworked crab fossils) on steep slope on north side of ridge, approximately 720 m east and 480 m north of the southwest corner of sec. 28, T. 17 N, R. 6 W, U.S. Geological Survey 7.5-minute South Elma Quadrangle, 1986 (provisional edition, minor revisions 1993), Grays Harbor County, Washington. Lower Miocene part of the Lincoln Creek Formation. Collectors: J. L. and G. H. Goedert, May 23, 1998.

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

1999 ANNUAL MEETING

APRIL 30–MAY 1, 1999

CALIFORNIA STATE UNIVERSITY

DOMINGUEZ HILLS

The Annual Meeting of the Southern California Academy of Sciences was held April 30–May 1 at California State University, Dominguez Hills. Student Award winners were as follows.

Margaret Barber Award for Best Paper
Steve I. Lonhart, Dept. of Biology, University of California, Santa Cruz

Feeding Preferences of Invasive and Native Turban Snail Predators

Jules Crane Award for Best Paper
Chugey Sepulveda, Dept. of Biological Science, California State University, Fullerton

Are Tunas Faster or more Efficient Swimmers as a Result of Endothermay?

Best Poster Award
Gloria Jean Baca, Dept. of Biological Science, California State University, Fullerton

The Effects of Lateral Line Development on the Escape Response (C-Start) of the California Halibut, *Paralichthyes californicus.* (Coauthors A. C. Gibb and K. A. Dickson)

Best Poster Award
Kristina D. Louis, Dept. of Organismic Biology, Ecology and Evolution, U.C.L.A.

An Investigation of the Subspecies of the Staghnorn Sculpin, *Leptocottus armatus* (Scorpaeniformes: Cottidae) (coauthors, A. Y. Han and D. K. Jacobs)

Honorable Mention

Kristin M. Ward, Pacific Estuarine Research Laboratory of San Diego State Univ.

Episodic Colonization of an Intertidal Mudflat by Cordgrass at Tijuana Estuary (Coauthors, J. C. Callaway and J. B. Zedler)

NEXT MEETINGS

MAY 5–6, 2000 at the University of Southern California
MAY 5–6, 2001 at California State University, Los Angeles

The Southern California Junior Academy of Sciences met concurrently with the Academy. Twenty-six students presented oral presentations and twenty-one papers were turned in for judging. On the basis of their oral presentations and written papers, the following students were selected to attend the National Meeting of the American Junior Academys of Science, to be held in Washington D.C. Feb. 16–20, 2000 in conjunction with the annual meeting of A.A.A.S.

Daniel Chen, Villa Park High School. Mentor: Ping Wang, U.C. Irvine

Insulin-Like Growth Factor I Retards Apoptotic Signaling induced by Ethanol in Cardiomyocytes.

Nathan Fleischaker, La Costa Canyon High School. Mentor: David Emmerson, La Costa

Development of an Anodic Stripping Voltammetry Electrode for Measurement of Heavy Metal Ions and its use in Monitoring Clean-up of Contaminated Soils

Sophia Tran, Alhambra High School. Mentor: Donn Gorsline, U.S.C.

Clay Mineral Groups in the Gulf of California

Michael Wang, Troy High School. Mentor: Christian Lytle, U.C. Riverside

Immunolocalization of NA-K-2Cl Cotransporter and Cl/HCO_3 Exchange Proteins in Human Stomach.

Elizabeth Williams, Palos Verdes High School, Mentor: Irving Biederman, U.S.C.

Perceived Lightness as a Measure of Perceptual Grouping

Terry Yen, West High School, Torrance. Mentor: Elisheva Goldstein, Calif. Poly. Univ. Pomona.

Theoretical Study of the Inhibition of HIV Protease by a Curcumin Boron Complex

The Southern California Academy of Sciences gratefully acknowledges the following organizations for their generous donations to the 1999 Annual Meeting:

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The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

The author should submit *at least two additional copies with the original,* on 8½ × 11 opaque, nonerasable paper, double spacing the entire manuscript. ***Do not break words at right-hand margin anywhere in the manuscript.*** Footnotes should be avoided. **Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.**

An abstract summarizing in concise terms the methods, findings, and implications discussed in the paper *must* accompany a *feature article. Abstract should not exceed 100 words.*

A feature article comprises approximately five to thirty typewritten pages. Papers should usually be divided into the following sections: abstract, introduction, methods, results, discussion and conclusions, acknowledgments, literature cited, tables, figure legend page, and figures. Avoid using more than two levels of subheadings.

A research note is usually one to six typewritten pages and rarely utilizes subheadings. Consult a recent issue of the BULLETIN for the format of *notes.* Abstracts are not used for notes.

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Taxonomic procedures: Authors are advised to adhere to the taxonomic procedures as outlined in the International Code of Botanical Nomenclature (Lawjouw et al. 1956), the International Code of Nomenclature of Bacteria and Viruses (Buchanan et al. 1958), and the International Code of Zoological Nomenclature (Ride et al. 1985). Special attention should be given to the description of new taxa, designation of holotype, etc. Reference to new taxa in titles and abstracts should be avoided.

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McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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Rare Species as Bioindicators in Marine Monitoring

Don Maurer[1], Tom Gerlinger[2] and George Robertson[2]

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Abstract.—Soft-bottom invertebrates commonly form the core of marine monitoring studies. Accordingly, those species which occur frequently and abundantly are favored in analyses, and rare species are normally excluded from consideration. Since rare species commonly occur at their geographic limits under suboptimal conditions, it has been postulated that they would be vulnerable to natural and anthropogenic stresses. We examined the potential of rare species as bioindicators in monitoring a major marine outfall on the San Pedro Shelf, California. A rare species was operationally defined as occurring only once per sample (0.1m^2 Van Veen Grab). Based on 780 quantitative benthic samples, distributed over thirteen 60 m (outfall depth) stations, and 12 years, we concluded that the number of rare species generally declined towards outfall stations. We suggested that a more conventional definition of rarity based on actual geographic range might provide an increased degree of sensitivity to identify bioindicators.

Soft-bottom macroinvertebrates commonly represent the basis of many marine monitoring programs (Bilyard 1987). In turn, the enumeration of macrobenthos depends on accurate identification (Brinkhurst 1980) prior to being quantitatively analyzed for measures of community structure (number of species, abundance, biomass, diversity, species composition) (Diener et al. 1995). Species richness is a focus of many ecological theories and applications (Cao et al. 1998). In addition, identification and enumeration of various species frequently reveal taxa as candidate bioindicators. The latter species are sensitive to a contaminant gradient by increasing or decreasing in abundance (Pearson and Rosenberg 1978). Bioindicators have been commonly used as major tools in monitoring programs (Wilson 1994). We have found that using groups or suites of species is preferable to relying on a single or a few species as bioindicators.

During the course of benthic surveys with a diverse fauna, a common practice among benthic ecologists is to exclude rare species from data analysis (Cao et al. 1998). There are several reasons for this. Species that occur frequently and abundantly dominate most of the functional processes on which an ecological community depends (Main 1982). As a result, they are preferred candidates as dominant species and bioindicators. According to Cao et al. (1998) rare species are routinely deleted from data sets because many workers believe they contribute little to community analysis and add noise to statistical solutions. Moreover, exclusion of rare species from quantitative analyses normally simplifies data pro-

cessing, thereby reducing problems frequently encountered in the analysis of data matrices containing large numbers of zeros (Harvey et al. 1998).

During its monitoring program the Districts has produced over 3000 quantitative samples yielding 2 million individuals and over 1200 species. Monitoring in Santa Monica Bay, California by the City of Los Angeles has produced about 2400 infaunal species (Dorsey et al. 1995). It is estimated that there are over 5000 marine benthic invertebrates in the Southern California Bight (SCB) (Thompson et al. 1993). Assuming the accuracy of this order of magnitude the SCB supports one of the richer bottom faunas in the world. This presents a huge task and challenge to practitioners analyzing data from the SCB.

From the body of work on rare species (Rabinowitz 1981; Groves and Ride 1982) we have adopted the construct that species are rare at the limit of their geographical and/or physiological range, and as such they occur under suboptimal conditions (Hummel et al. 1995). Cao et al. (1998) cite literature asserting that small populations are more likely to go extinct, and therefore rare species should be more sensitive to disturbance than common ones. If the premise is valid, then rare species might be particularly vulnerable to stresses imposed by natural processes and anthropogenic activities. In this account we focus on frequency of occurrence in samples from the study area as a measure of rarity rather than actual geographic ranges of incumbent species.

In any faunistic survey it is a common observation for a collection of species that some occur in relatively few samples and/or occur at relatively low abundances (Schoener 1987). The growth of a species or a population in its habitat is subjected to constraints (Grieg-Smith and Sagar 1981). If those constraints are relaxed population size may increase, if they are exercised, populations may decrease or grow and develop more slowly. Causes of rarity are found by identifying the constraints on the potential rate at which the population size of the selected species can increase. Anthropogenic activities can provide constraints unrelated to natural processes.

There is a considerable literature on rare species, rarity or rarities (Preston 1948, 1962, 1980; Harper 1981; Groves and Ride 1982; Schoener 1987; Prendergast et al. 1993; Boero 1994; Gaston 1995). Criteria for defining rarity may involve uniqueness, relict nature, frequency of occurrence, functional role in community dynamics, geographic range, habitat specificity, and local abundance (Rabinowitz 1981; Main 1982). For the present account rare species are operationally defined as those species occurring once per sample (0.1 m^2 Van Veen Grab).

A practical purpose for monitoring is to ascertain the status of particular populations or species (Davy and Jeffries 1981). Successful management of a rare population, making it less rare or preventing its local extinction, implies the ability to manipulate the size and structure of that population. If monitoring is to contribute significantly to this ability, it must yield a predictive understanding of population structure and function. Accordingly, monitoring based on enumeration of species is most relevant to problems of rarity (Davy and Jeffries 1981; Cao et al. 1998). This argument provides support for the definition of rarity used herein.

Boero's (1994) discussion of fluctuations and variations in coastal marine environments provides a useful point of departure. According to him the higher the number of rare species available to replace the dominant species, the higher the possibility for a community to successfully face important disturbances. Gray

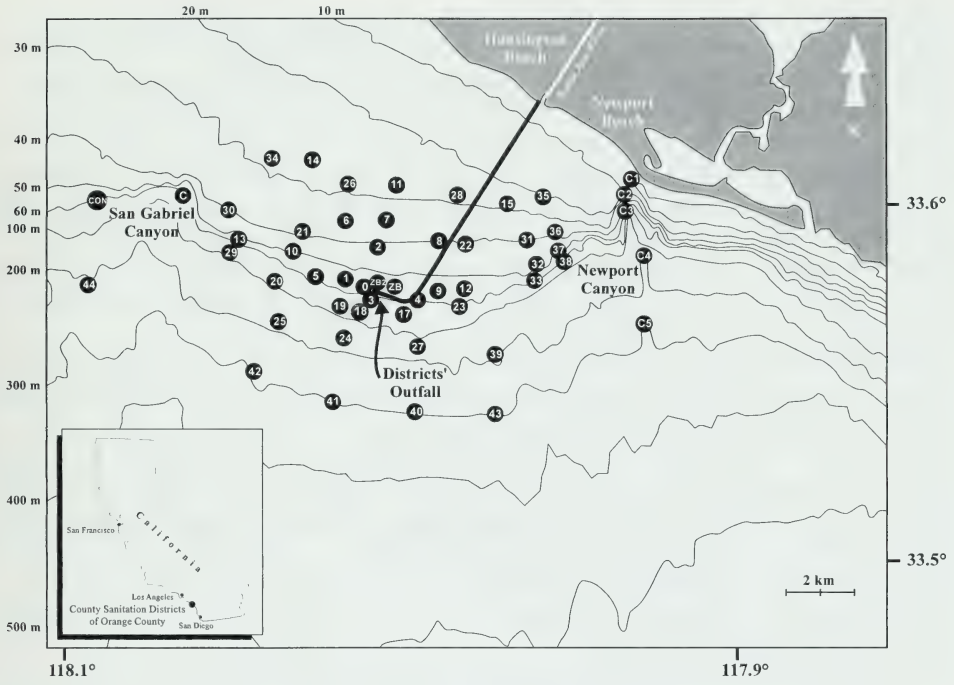

Fig. 1. Benthic sampling stations from the San Pedro Shelf, California.

(1989) expressed the view that in most unstressed communities there are many rare species contributing to high species richness. Recalling our earlier characterization of the relative vulnerability of rare species to natural and anthropogenic stresses compared to common species, the number of rare species might be expected to decline towards an ocean outfall (Hummel et al. 1995; Cao et al. 1998). Moreover, stress may also be imposed by increased abundance of organisms due to organic enrichment. It occurred to one of the authors (TG), that if rare species are more responsive to stress than common ones, the former should be included on a more regular basis as a tool in marine monitoring. This would greatly elevate their ecological significance, and serve as a stimulus fostering studies of natural history and population dynamics of species generally ignored for this purpose. Accordingly, we examined the proposition that the number of rare species should be lower in the vicinity of an ocean outfall.

Materials and Methods

Field.—From 1985 to the present the Districts has collected benthic samples of sediment and macrobenthic invertebrates with a double yoked 0.1 m^2 Van Veen grab from an array of stations on the San Pedro Shelf, California (Fig. 1). Sampling stations were located by Loran C and/or GPS (+ or − 15 m) and samples were sieved through a 1.0 mm mesh screen which is the accepted mesh size in the SCB. Specimens were fixed in 10% buffered formalin and subsequently transferred to 70% ethanol in preparation for laboratory analyses.

From 1985 to the present the Districts has sampled annually (summer) 40 stations (N = 1) extending from 30 m to 324 m, and thirteen 60 m stations (N

= 5) quarterly (winter, spring, summer, fall), totaling over 3000 quantitative benthic samples for this monitoring program. In the summer of 1994 the Districts participated in the SCB Pilot Project (Bergen et al. 1998) which precluded regular sampling, and so this year is deleted from quantitative analyses in the present account. Based on this extensive sampling effort, collections from the summer characteristically yield the highest number of macrobenthic species (Districts 1995). Moreover, the thirteen 60 m stations were established to permit quarterly sampling on the same isobath as the ocean outfall, thus reducing the effect of depth on variation of estimates of community measures. For purposes of this account we have focused on the thirteen 60 m stations sampled during the summer from 1985 to 1997. Analyses are based on 780 benthic samples.

Taxonomic analyses.—From the 780 sample database a rare species was defined as one individual per 0.1 m^2 grab. Single occurrences were extracted from the database. To provide conservative estimates of rarity for this analysis we applied some degree of filtering for inclusion. Mysids, euphasusiids, pteropods, calanoid copepods, larvae and other plankton collected during sampling were excluded from counts together with fishes and their parasites. Since the analysis focuses on benthic species, inclusion of planktonic and nektonic species would be inappropriate. Collected nematodes, harpacticoid copepods, and halacarids were also excluded because the sampling gear and sieving protocols preclude accurate sampling of these small organisms.

In addition, taxa with plural notations in the taxonomic listings (*Macoma* spp.) were not included because of uncertainty about the actual number of species represented by such a designation. The same convention was applied to a genus identified as a juvenile (*Amphiodia* sp. juvenile). Finally, higher taxonomic categories (phylum, class, order, family, genus) were excluded from rare species designation unless listed with a species designation (Phoronid species B).

Statistical analyses.—After the number of rare species was tabulated, they were ranked according to station. Since this account focused on the presence or absence of rare species, we used the non parametric Kruskal-Wallis test with ties, an analysis of variance by ranks to test whether there were any statistically significant ($\propto$ = 0.05) differences in rarity across stations (Zar 1984). For the Kruskal-Wallis test H_0 was that the number of ranked rare species did not differ across stations. When H_0 was rejected, a nonparametric multiple comparison was applied to determine between which of the stations significant differences occurred. For the latter test we assumed a one-tailed distribution.

When the nonparametric multiple comparison indicated significant differences in ranked rare species among stations, we used the nonparametric Mann-Whitney (U) distribution (Zar 1984). For the Mann-Whitney distribution we compared the number of ranked rare species at a reference station (CON) with those from the Zone of Initial Dilution (ZID) stations (0, ZB, ZB2, 4). We also assumed a one-tailed distribution for these analyses.

Results

Number of rare species.—The average number of rare species per thirteen 60 m stations (1985–1997) was computed (Table 1). Examination of these data revealed the following trends. First, the average number of rare species increased from the 1980s (37–38) into the 1990s (47–48) (Fig. 2). Second, rare species

Table 1. Average number of rare benthic species from 13 60 m annual (summer) stations from the San Pedro Shelf, California 1985 to 1997.

Year	1985		1986		1987		1988		1989		1990		1991		1992		1993		1995		1996		1997	
Station	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
CON	41.6	6.5	43.2	6.6	46.4	9.0	47.8	8.6	39.2	6.0	44.8	2.9	48.8	1.5	50.6	6.9	45.4	8.2	52.2	12.9	52.4	3.9	50.6	3.9
C	39.2	4.4	42.2	5.8	45	2.8	49.6	7.3	50.2	10.3	41.6	6.6	42.2	4.5	50.2	7.6	45	2.9	51.6	6.5	57.2	4.0	55.8	3.8
13	46	3.2	37.4	8.4	37.6	10.7	46.6	6.2	48.6	4.9	37.8	7.2	36.8	4.2	41.6	11.1	46	7.7	44.2	4.3	48.0	3.9	50.8	3.9
5	44.2	7.5	40.8	7.5	42	9.2	41.6	8.0	43	4.7	35.6	10.0	46	7.8	45.6	3.6	47	4.8	50.2	6.1	51.0	3.9	48.8	3.9
1	33.6	7.8	45.6	4.2	40	7.8	40.0	6.0	41.8	3.6	35.2	2.9	36.4	5.2	41.8	2.8	34.8	6.3	48.8	1.8	51.6	3.9	49.6	12.3
0	34.6	6.1	43.1	6.2	35.6	7.3	38.2	44	34.2	5.4	38.6	6.1	31.2	3.0	31.2	5.0	32.2	2.9	39.2	6.8	42.0	3.7	42.4	3.7
ZB2	39.4	4.3	34	6.8	32.8	8.9	35.4	10.7	32.4	6.7	34.6	5.9	31.4	2.5	38.4	8.5	38.2	5.4	39.2	6.0	32.8	3.5	41.4	3.7
ZB	39.4	11.0	35.6	8.3	31.6	7.1	23.8	3.1	29.4	4.8	30	5.7	29.8	6.9	36	3.5	42.4	8.6	40.0	3.7	39.6	3.7	38.2	6.4
4	36.8	5.1	39.6	6.0	39.6	4.3	43.0	4.8	33.2	4.1	30.2	2.2	36.2	4.9	40.2	1.9	43.8	4.4	51.6	3.8	50.6	3.9	48.8	3.9
9	41.0	3.7	42.4	6.2	46.4	9.8	46.6	9.9	32.7	4.9	35	6.4	40.6	2.6	42	5.1	43.8	4.6	58.4	8.8	56.8	10.4	54.6	4.0
12	43.1	4.8	42.8	1.6	42.8	3.3	37.8	5.2	32.6	6.0	27.4	2.6	36.6	3.9	41	6.3	38	3.7	52.4	3.9	56.8	4.0	52.6	3.9
37	42.5	4.7	47.8	9.0	41.2	7.6	51.4	11.3	50.4	6.6	45	10.4	42.4	5.7	45.8	11.3	53.8	5.4	52.6	3.9	65.8	4.2	55.6	4.0
C2	18.8	5.8	10.6	5.2	13.2	4.3	18.2	6.1	19.4	4.4	17	3.9	12.4	1.1	18.4	3.5	14.6	1.3	17.8	2.9	22.2	3.1	22.2	3.1
$\bar{x}$	38.5		38.7		38		40		37.4		34.8		35.6		40.2		40.4		46		48.2		47	

Legend: $\bar{x}$ = Mean; SD = Standard Deviation; Station = N = 5
* 1994 SCB Pilot Program

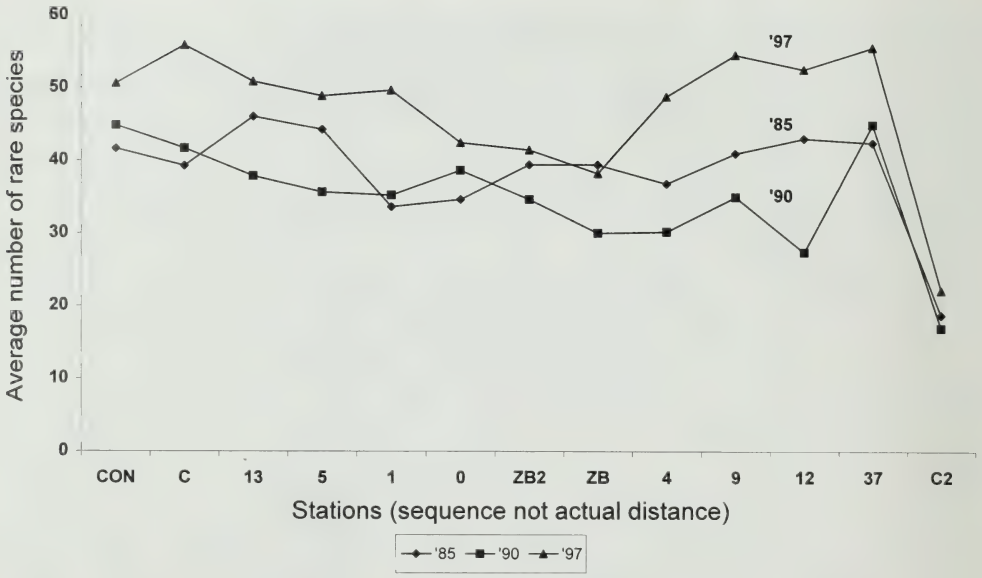

Fig. 2. Average number of rare benthic species from 13 60m stations on the San Pedro Shelf, CA 1985, 1990, and 1997.

were always lowest at Station C2 located in the Newport Submarine Canyon (Table 1, Fig. 1–2). Third, rare species were generally higher at farfield stations (CON. C, 13, 37). Fourth, the average number of rare species was generally lower at ZID stations compared to other 60 m stations (Fig. 2). The average number of rare species from 1987 were plotted as representative of the data base (Fig. 3). The marked decline of rare species at C2 in the canyon and the saddle posed by the ZID stations is very clear. However, at various times as many as 57–58 rare

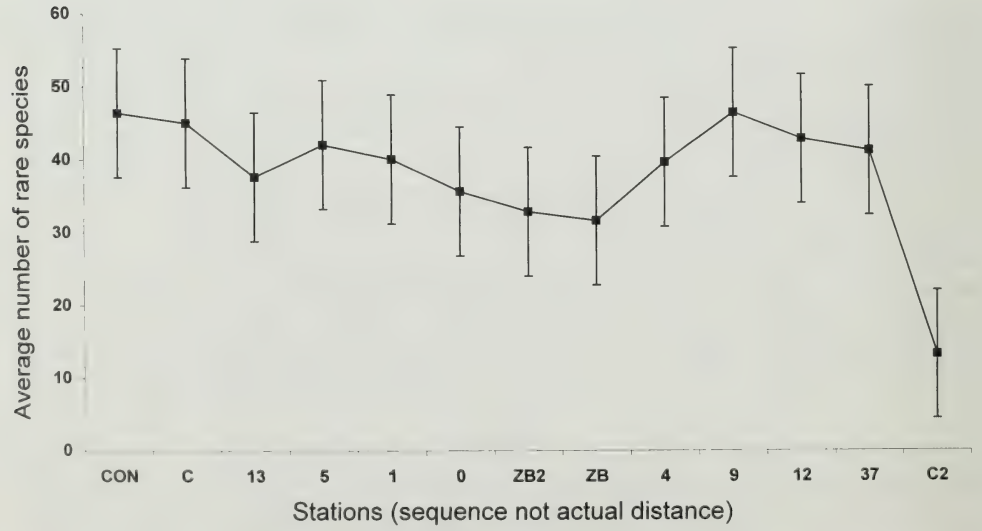

Fig. 3. Average number of rare benthic species from 13 60m stations on the San Pedro Shelf, CA 1987. *Error bar equals 1 standard deviation.

species were recorded from ZID stations. This attests to the richness and status of the macrobenthos from this portion of the San Pedro Shelf.

Rank number of rare species.—The rank number of rare species was computed (Table 2). These data reflected the trends noted for the average number of rare species (Table 1). Station C2 always received the lowest ranks. Moreover, ranks were usually lower at the ZID stations (0, ZB, ZB2, 4) compared to the nearfield (1, 5, 9, 12) and farfield stations (CON, C, 13, 37) (Table 2, Figure 1).

Kruskal-Wallis tests were performed on the ranks of rare species. Ranks were always significantly ($\propto = 0.05$) lower at Station C2 (Figure 1) compared to other 60 m stations. As a result, data from Station C2 were deleted from remaining analyses (Table 3). Based on the computed H_c value compared to the tabled H_c (Zar 1984), the null hypothesis (H_0 = there were no differences in the number of ranked rare species across stations) was rejected eight of twelve years. When H_0 was accepted, critical values were very close for significance for three years (1985, 1987, 1996).

For those years when H_0 was rejected a nonparametric comparison was applied to distinguish significant ranking of rare species among stations (Table 3). A major trend was that ranks of rare species from ZID stations were commonly grouped and were significantly ($\propto = 0.05$) lower than those at other 60 m stations (Table 3).

To examine further the H_0, the Mann-Whitney (U) distribution was employed comparing ranks of rare species at reference Station CON with those at ZID stations (Table 4). For these comparisons the null hypothesis (H_0 = the number of ranked rare species is not higher at CON compared to ZID stations) was rejected 23/48 (47.9%), accepted 17/48 (35.4%), and received 8/48 (16.7%) ties (accept/reject) where computed U was equal to the tabled critical U (Table 4, Zar 1984).

The average number of rare species and the rank number of rare species was generally lower at ZID stations than other 60 m stations (Table 1 and 2). Kruskal-Wallis analyses indicated that ranked rare species differed significantly across stations (Table 3). Moreover, the nonparametric multiple comparisons indicated that ranked rare species at ZID stations commonly grouped together and were significantly lower than those from nearfield and farfield stations. Although not without exceptions, the Mann-Whitney distribution further indicated significant separation between CON and the ZID stations. The weight of evidence supports the proposition that the number of rare species was lower in proximity to the ocean outfall.

Discussion

Several trends emerged from this account. Earlier it was noted that the average number of rare species increased from 1985 through 1997 (Fig. 2). This might be interpreted as increased immigration and successful colonization of benthic species to the study area due to improved environmental conditions. Increased source control and upstream recycling together with reduced emission of total suspended solids to the ocean has markedly reduced concentrations of many trace metals and organic contaminants (Districts 1995). Thus, there is solid evidence to support the position that environmental conditions have improved around the outfall from 1985 through 1997. Regardless, the increased number of rare species with time is probably due to increased refinement in taxonomy as the monitoring program has matured. Since this pattern is distributed across all stations including the 40 annual ones (Fig. 1), it does not affect the results of the study.

Table 2. Rank number of rare benthic species from 13 60 m annual (summer) stations (N = 5) from the San Pedro Shelf, California 1985 to 1997.

1985	C2	1	0	4	ZB	C	ZB2	9	37	CON	5	12	13
	19	101.5	102.5	129	150.5	161	162	188	192.5	203	227.5	242	266.5
1986	C2	ZB2	ZB	13	4	0	9	C	CON	12	5	1	37
	15	94	107	139	156.5	165	183.5	185	197	206	218	238	239.5
1987	C2	ZB	ZB2	0	1	13	4	37	5	12	9	CON	C
	16	85	103	128.5	155	166	166.5	194.5	203.5	212.5	229	234	251
1988	C2	ZB	ZB2	0	12	1	5	4	9	13	CON	37	C
	23	38	123.5	129.5	135.5	153	179.5	188	223.5	229.5	241	248	254.5
1989	C2	ZB	9	ZB2	4	12	0	CON	1	5	C	13	37
	21.5	78	106	108.5	111	111.5	130	192	215.5	229.5	274	280.5	287
1990	C2	12	ZB	4	ZB2	1	9	5	13	0	C	37	CON
	16.5	71.5	102	104	159.5	163.5	165	187	194	207.5	237	257.5	280
1991	C2	0	ZB	ZB2	4	1	12	13	C	9	37	5	CON
	15	83.5	85	85.5	149.5	154.5	156	62	196	220	229.5	265	303.5
1992	C2	0	ZB	ZB2	13	1	12	9	37	5	4	C	CON
	15	65.5	101	143.5	161	173	174	178	223.5	227.5	253	261	269
1993	C2	0	1	12	ZB2	ZB	4	9	CON	C	13	5	37
	15	59.5	94.5	117	124	166	194.5	195.5	203.5	207	218	230	291.5
1995	C2	ZB	ZB2	0	13	1	5	CON	C	37	12	4	9
	15	77	82	86	130	187.5	198.5	201.5	213	216	220.5	223.5	262
1996	C2	ZB2	ZB	0	13	4	9	5	1	CON	12	C	37
	17.5	47.5	79.5	95.5	156	180.5	181.5	182.5	195	212.5	236	247.5	279
1997	C2	ZB	ZB2	0	1	4	5	CON	13	12	37	9	C
	15	67	79.5	100	164.5	167.5	171.5	189.5	202.5	215.5	226.5	245	260.5

Legend:
First Line = Station Number
Second Line = Sum of Ranking Per Station Per Year

Table 3. Summary of H_0 results (N = 12 stations) from Kruskal-Wallis analysis and nonparametric multiple comparison 1985–1997.

Year	Kruskal-Wallis			Nonparametric Multiple Comparison Station Separation
	Estimated H_c	Tabled H_c	Decision	
1985	19.3	19.6	Accept	
1986	15.6		Accept	
1987	19.5		Accept	
1988	27.1		Reject	C 37 CON 13 9 4 5 1 12 0 ZB2 ZB
1989	42.7		Reject	37 13 C 5 1 CON 0 12 4 ZB2 9 ZB
1990	26.1		Reject	CON 37 C 0 13 5 9 1 ZB2 4 ZB 12
1991	81.1		Reject	9 CON 5 C 37 13 12 1 4 ZB2 ZB 0
1992	58.4		Reject	CON C 5 4 37 12 1 13 9 ZB2 ZB 0
1993	31.9		Reject	37 5 13 C CON 9 4 ZB ZB2 12 1 0
1995	22.0		Reject	9 4 12 37 C CON 5 1 13 0 ZB2 ZB
1996	19.3		Accept	
1997	20.4		Reject	C 9 37 12 13 CON 5 4 1 0 ZB2 ZB

Another trend cited earlier involved Station C2 (Table 1 and 2). Extensive sampling of benthic organisms, sediment properties, and sediment geochemistry has demonstrated that the physical oceanography and associated hydrodynamic regime of the Newport Canyon (Fig. 1–3) is dramatically different from other 60 m stations. The hydrodynamic regime produced different conditions for sediment properties and benthos alike (Districts 1995). Accordingly, it was not surprising that the average number and rank of rare species was significantly lower at Station C2 in the canyon (Fig. 2–3) and so its exclusion from further analyses was justified.

Although not without exceptions, the principal trend from this study revealed a reduction of rare species in proximity to the outfall (Table 1–4, Fig. 2–3). This trend agrees with the work of other researchers (Gray 1989; Boero 1994; Cao et al. 1998) which suggests that the distribution and abundance of rare species might be useful in marine monitoring.

In the present account a rare species was operationally defined as being collected once per 0.1 m^2 rather than adopting a conventional definition based on geographic distribution. The operational definition was used to entertain the construct and to initiate discussion emphasizing the importance of including rare species in analyses of marine monitoring. This approach also maximizes information rather than characteristically discarding presumably useless data. Exclu-

Table 4. Summary of Mann-Whitney (U) distribution comparing rank order of rare species at Station CON with ZID Stations (0, ZB2, ZB, 4) 1985 to 1997.

Year	Station			
	0	ZB2	ZB	4
1985	21=21	19.2<21	16<21	17.5<21
	Accept/Reject	Accept	Accept	Accept
1986	15<21	21.5>21	21=21	15.5<21
	Accept	Reject	Accept/Reject	Accept
1987	20<21	22>21	23.5>21	18<21
	Accept	Reject	Reject	Accept
1988	21=21	21=21	25>21	19<21
	Accept/Reject	Accept/Reject	Reject	Accept
1989	18<21	21=21	23>21	21=21
	Accept	Accept/Reject	Reject	Accept/Reject
1990	21=2	24>21	25>21	25>21
	Accept/Reject	Reject	Reject	Reject
1991	25>21	25>21	25>21	25>21
	Reject	Reject	Reject	Reject
1992	25>21	23>21	25>21	23.7>21
	Reject	Reject	Reject	Reject
1993	23>21	20<21	18<21	16.7<21
	Reject	Accept	Accept	Accept
1995	21=21	21.5>21	20.5<21	11<21
	Accept/Reject	Reject	Accept	Accept
1996	24.5>21	25>21	24>21	18.4<21
	Reject	Reject	Reject	Accept
1997	20.5<21	22.2>21	23>21	14.5<21
	Accept	Reject	Reject	Accept

1st number = Estimated Mann-Whitney U.
2nd number = Critical value of Mann-Whitney U distribution.
Underline = statistically significant $\propto$ = 0.005 (1), n = 5, n = 5.

sion of rare species seriously violates general ecological observations and theory leading to unacceptable losses of ecological information (Cao et al. 1998). Although some of the species included in the analyses may be rare according to geographic convention, that is, they occur near or at the limit of their geographic range, we presently do not know how many of the species used herein fall into this category. The operational definition may be overly simplistic in framing the physiological condition of rare species, thus reducing their sensitivity to respond to the potential stress (abiotic or biotic) posed by the outfall.

Cao et al. (1998) examined the response of rare species as defined by occurrence frequency to an aquatic gradient of contaminants. They concluded that exclusion of rare species coupled with small sample size can influence comparison of species richness compromising the reliability and sensitivity of community analysis and bioassessment. Rare species are critical for accurate community studies and bioassessment (Cao et al. 1998).

An anonymous reviewer noted that this view contrasts with the practice of taxonomic sufficiency advocated by researchers from the U. S. EPA (Ferraro and Cole 1990, 1995). Taxonomic sufficiency involves identifying organisms only to the taxonomic level necessary to meet study objectives assuming no loss of statistical rigor. According to its proponents the practice minimizes the time, cost,

and error of taxonomic identification. Taxonomic sufficiency is a cost-benefit exercise. Clearly an analysis focusing on rare species places a demand on accurate identification and is not consistent with the savings attributed to taxonomic sufficiency. While recognizing that opportunities for cost savings associated with long-term monitoring deserve serious consideration, there are a number of other implications to taxonomic sufficiency which have not been addressed, and which should be considered prior to implementing this as a regular monitoring protocol. We have prepared a fuller rebuttal in a manuscript in preparation.

Harper (1981) placed emphasis on the role of pathogens controlling natural plant populations of rare species. By analogy effluent from the outfall could serve as a medium for invertebrate pathogens potentially exerting negative pressure on benthic populations. However, there is no evidence to support that the outfall serves as the basis of an epizootic condition for invertebrates (Districts 1995).

We conclude that the definition of rarity used herein provides evidence for using rare species as bioindicators in analyses of marine monitoring. This assertion derives independent support from the work of Cao et al. (1998). Alternatively, rare species defined through geographic conventions may provide an increased degree of sensitivity for this purpose. Since polychaetes and amphipods provide diverse taxa for SCB soft-bottom communities, they would seem to be likely candidates for identifying rare species based on their geographic range. Notwithstanding the extensive taxonomic work on polychaetes and amphipods by Hartman (1968, 1968) and Barnard (1969), respectively, new species of both taxa are still being identified by the Southern California Association of Marine Invertebrate Taxonomists. Thus, the geographic range of new species of polychaetes and amphipods and existing ones remains to be determined. As a first start we suggest that molluscs with their extensively documented geographic ranges (Morris 1966; Abbott 1974) and ecologic importance to benthic communities would be a good candidate taxon to initiate refined analyses of rare species in marine monitoring.

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Morphologic and Genetic Variation Among Six Populations of the Spotted Sand Bass, *Paralabrax maculatofasciatus*, from Southern California to the Upper Sea of Cortez

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Abstract.—Spotted sand bass, *Paralabrax maculatofasciatus*, were examined for 19 morphometric and 7 meristic characters to determine the extent of morphologic and genetic variation among six Pacific and Gulf of California populations. Polymerase Chain Reaction (PCR) and Restriction Fragment Length Polymorphism (RFLP) techniques were used to amplify and cleave the ITS region of the rDNA in order to detect differences among these populations. The morphological and genetic lines of evidence demonstrate that significant differentiation has occurred between the most distant Gulf and Pacific regions. The three Baja California populations share significant morphological and genetic affinity and appear to be different from the three Pacific populations. There is no significant morphologic differentiation between the three Pacific populations although genetically they form two different groups. The northernmost Pacific population of San Diego is significantly different from the two southern-Pacific groups as well as the entire gulf sample. The results of this study indicate that geographically isolated populations of nearshore marine fishes, under the influence of strong selection pressures, do not require long periods of time for divergence. The last 15,000 years may have been sufficient to allow significant divergence to occur between upper Gulf and Pacific groups of the spotted sand bass.

The spotted sand bass, *Paralabrax maculatofasciatus*, is a serranid native to the eastern Pacific Ocean, having a historical range of San Francisco Bay south to Mazatlan, Mexico. Spotted sand bass rarely occur north of Santa Monica Bay (Love 1991) and are exceedingly rare in the warmer tropical waters of the southern cape region at Cabo San Lucas (Thomson and McKibbin 1976). Dense populations occur in the northern Gulf of California and also in the southern California region where they are restricted to shallow, warm-water back bays and harbors and the protected outer coast which provide warm-water refuges for this largely subtropical species (Fitch and Lavenberg 1975; Allen et al. 1995a). Tagging studies conducted by Allen (pers. obs.) throughout southern California have shown that spotted sand bass are nonmigratory and remain in their distinct region of settlement. This species leads a relatively sedentary lifestyle in association with a particular bay, harbor, or open coast rock relief structure. Gene flow and dispersal are facilitated through the long distance movement of eggs and larvae by ocean currents, and settlement from the plankton occurs at approximately 21 days

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(Smith 1996). Spotted sand bass live to a maximum of 14 years although the average age is 6 to 10 years old. Sexual maturity is reached within the first year. Sizes up to 450 mm. standard length (SL) and 2.6 kg can be reached but individuals larger than 330 mmSL are rare (Allen et al. 1995a).

Many of the fish species which occur in the upper Gulf of California are also found on the Pacific side of southern and Baja California and are absent or rare at the southern cape region of Baja California. This disjunct distribution is shared by 42 ecologically diverse fish species belonging to 28 families (Hubbs 1960; Walker 1960; Present 1987). Highly mobile and sedentary species (Hubbs 1960; Walker 1960) as well as viviparous (Miller and Lea 1972) and planktonic spawning species are represented. Fish species composition in the Gulf places it as part of the Panamic faunal province (Walker 1960). Approximately 75% of the shorefish have a principal range south of the Gulf. About 8% range north of the gulf and are mostly disjuncts from southern California while 17% are endemic to the Gulf (Walker 1960).

Ocean floor spreading separated southern Baja California from mainland Mexico approximately 5.5 million years ago and has subsequently opened the Gulf 260 km to the northwest (Larson et al. 1968; Spencer et al. 1989). It is widely held that the distinct Pacific and Gulf faunae were apparently established during the most recent of nine Pleistocene glaciation events. The maximum southerly extension of the most recent glaciation occurred approximately 18,000 years ago. Moore et al. (1980) estimate that cooler (by approximately 2–4 °C) sea surface isotherms were shifted sufficiently south of the cape to allow free movement of species otherwise limited by higher sea surface temperatures in this region. The colder waters in the north forced the temperate and subtropical species to the warmer southern waters in order to maximize feeding and reproduction rates (Webb 1992). Walker (1960) discusses the possibility of a late Pleistocene seaway in the La Paz region which would have allowed for movement between Pacific and Gulf regions although the occurrence of such a waterway has not yet been established (Durham and Allison 1960). As the ice sheet began to recede to the north, approximately 15,000 years ago, the current day fauna returned and the Pacific and Gulf distribution was probably established well before the disappearance of the ice sheet.

The magnitude of isolation provided by the Baja peninsula is unknown and most likely varies according to each species' ability to move long distances or disperse eggs and larvae. In addition to the Baja peninsula, oceanographic barriers such as currents and isotherms (Cowen 1985) as well as chemical cues may affect larval dispersal routes. The spotted sand bass occupies a 3200-km range, which is unusually wide for a nearshore marine fish. However, in southern California, adults are restricted to definable populations and large scale movement is unlikely due to discontinuities of suitable habitat (Allen, unpubl. data).

The extent and direction of larval dispersal in this species is unknown. Plankton studies by Butler et al. (1982) found that *Paralabrax* eggs and larvae were confined mostly shoreward of the 36-mile contour off the mainland. California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise data from 1951–1984 report that serranid larvae occur as far as 250 km off of the southern and Baja California Pacific shoreline (Moser et al. 1993). The abundance of serranid eggs and larvae relative to all species sampled (Moser et al. 1993) was approximately

0.2%. At these latitudes the serranid larvae are most likely to be *Paralabrax* spp. One aggregation of serranid larvae was reported throughout the Channel Islands within the Southern California Bight. Another region of high larval density occurred off the central Baja, Pacific coast, stretching from Bahia de San Quintin beyond the tip of the peninsula. Within the Gulf, considerable mixing occurs in the northern regions (van Andel 1964). The relative abundance of serranid eggs and larvae were approximately 1.5% relative to all species sampled (Moser et al. 1986).

Investigators have used both morphological and molecular techniques to determine if gene flow is restricted between Gulf and Pacific populations. Morphological analyses can provide insight into the degree of adaptive differentiation which has occurred between disjunct populations. Although this may be reflected genetically and imply limited gene flow between regions, it is imperative to investigate the amount of genetic differentiation through more direct methods (Patterson 1987). Morphological differentiation has been reported in Gulf and Pacific populations of *Hypsoblennius jenkinsi* (Losey 1968), *Sebastes macdonaldi* (Chen 1975), and *Zalembius rosaceus* (Congleton 1968). Morphological differentiation has also been reported among *Girella, Sebastes*, and *Leuresthes*, all of which are recognized as having closely related Gulf and Pacific species. Protein electrophoretic variability indicates that gene flow is limited between disjunct Pacific and Gulf populations of *H. jenkinsi* (Present 1987) and between *Girella nigricans* and *Girella simplicidens* (Orton and Buth 1984) with no fixed allelic differences. Fixed allelic differences were found between *Leuresthes* populations (Crabtree 1983).

The use of ribosomal DNA (rDNA) in restriction fragment length polymorphism (RFLP) studies is commonly used in population biology (Zhuo et al. 1994; Jensen et al. 1993; Hall 1992; Phillips et al. 1992; Hillis and Moritz 1990). The rDNA unit occurs as clusters of tandem repeats located in the nucleolar organizing region (Long and Dawid 1980; Learn and Schaal 1987). In most vertebrates, this repeat unit consists of two nonconserved internal transcribed spacers, ITS-1 and ITS-2, flanked by three highly conserved gene coding regions, 18S, 5.8S, and 28S. Two external transcribed spacers (3′-ETS and 5′-ETS) flank the 18S and 28S genes and each repeat unit is separated by an intergenic spacer region (IGS). The internal and external transcribed spacers (ITS-1, ITS-2, 3′-ETS, and 5′-ETS) as well as the IGS region evolve more rapidly and can be used for comparisons of closely related species and geographically distant populations. The gene coding regions (18S, 5.8S, and 28S) evolve more slowly and are suitable for use in phylogenetic studies (Fain et al. 1992; Phillips *et al.* 1992; Learn and Schaal 1987). Furthermore, the number and location of ITS repeat units on the chromosomes varies among species (Allard *et al.* 1990). Mutations occurring within these repeat units can spread rapidly and homogenize within an interbreeding population (Silberman and Walsh 1992). Differences of restriction sites within the ITS regions due to the accumulation of mutations will result in restriction fragments that are unique to a particular population. Those populations that are most genetically similar will have more restriction sites in common and this can be determined through the comparison of RFLP banding patterns.

The purpose of this investigation was to determine the extent of morphological and genetic variation among Gulf and Pacific populations of the spotted sand

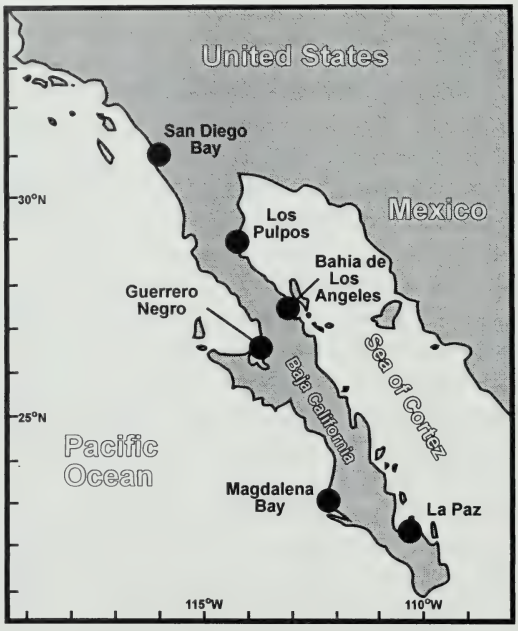

Fig. 1. Map showing six collection sites from southern California and Baja, California, Mexico.

bass. If gene flow is limited between these regions, this system would provide an excellent opportunity to investigate the effects of isolation on the process and rate of speciation since a Pleistocene establishment has been estimated for the time of separation (Hubbs 1960; Walker 1960).

Materials and Methods

Collection and preservation of specimens.—Spotted sand bass were collected between March 1993 and January 1995 with hook and line angling. Fish were collected from six sites along the entire range of this species (Fig. 1). The three Pacific sites sampled were San Diego, Guerrero Negro, and Magdalena Bay and the three Gulf sites included Los Pulpos, Bahia de Los Angeles, and La Paz. Whole live specimens were immediately placed in individually labeled plastic bags, stored on ice and transported to California State University, Northridge. Gill filament tissue was clipped in the field with forceps and tweezers and placed into 1.5 ml. microfuge tubes containing 5X NET buffer (2.5M NaCl, 0.25M EDTA, 0.25M Tris Base, pH 8.0). Tubes were labeled according to location and time of capture and stored on ice until transfer to freezers at the laboratory.

Morphological analysis.—A total of 30 *P. maculatofasciatus* individuals were collected from each site (n=180). Hook and line sampling limited the range of specimens to 110–307 mm. standard length. In total, seven meristic counts and nineteen morphometric measurements were made on each individual according to Cailliet et al. (1986). Measurements were made to the nearest 0.01mm with Mitutoyo CD-6B digital calipers.

Genetic analysis.—A total of 15 specimens from each of the six sites were analyzed for variation within the ribosomal DNA repeat unit. Total nuclear genomic DNA was extracted using the G-NOME Kit protocol from BIO 101, Inc.

DNA concentration and purity (absorbance at 260/280 nm) were estimated using a Beckman DU-64 spectrophotometer. DNA concentrations of sample stock were adjusted to 0.15 μg/μl by the addition of TE buffer (pH 8.0). The two internal transcribed spacer regions (ITS 1 and ITS 2) and the 5.8S subunit were amplified by polymerase chain reaction (PCR). Primers complimentary to the 28S and 18S flanking regions (Hillis and Dixon 1992) were purchased from Integrated DNA Technologies, Inc. Primer 28u has a 21 base sequence (5′-CGTTACTGGGGGAATCCTGGT-3′) and primer 18s has a 27 base sequence (5′-CACACCGCCCGTCGCTACTACCGATTG-3′). The following PCR reaction parameters were used: 0.75 μg of template DNA, 0.75 μM of each primer (18D and 28U), 0.15 mM dNTP's, 3.0 mM $MgCl_2$, 1.2 μl of 10× buffer, and 1 U Taq polymerase in a 20 μl reaction. Taq polymerase was pipetted into the mixture after an initial 8-minute heat shock phase. The following thermocycle conditions were used: 30 cycles consisting of a 95 °C denaturing step for 45 seconds, a 60 °C annealing phase of 45 seconds, and a 72 °C elongation period of 1 minute. These cycles were followed by a 5-minute elongation phase at 72 °C and then a 5 °C storage until removal from the thermocycler. PCR products were subjected to digestion in a 37 °C or 60 °C waterbath (depending on the reaction requirements) for 16 hours with 1U of a restriction endonuclease. The following restriction enzymes were used: *BstU*I, *Dpn*II, *Hha*I, *Hae*III, *Msp*I, *Rsa*I, *Taq*αI, *Hind*III, *Stu*I, *Nci*I, and *BamH*I (purchased from New England BioLabs). Electrophoresis was conducted on a 65 ml 2.5% TBE agarose gel in 1× TBE buffer at 90 volts for 2 hours. New England Biolab's ΦX174 *Hae*III size marker was loaded onto each gel in order to determine fragment size. RFLP's produced by endonuclease restriction were examined on an ultraviolet transilluminator and captured with the UVP ImageStore 5000 (Beaumont, CA) gel documentation system. The captured gel images were analyzed with UVP's SW 5000 GelBase™ Windows software program and all fragment sizes were estimated in base pair lengths.

Data analysis.—Statistica for Windows was used for data analysis and graphical representation. The morphological data were log-transformed in order to reduce the correlation of measurement variances and means (Sokal and Rohlf 1981). Body counts in most fishes do not usually covary with growth after a threshold body size is reached (Strauss 1985). Meristic data were not transformed and were treated separately from measurement data. A stepwise multiple discriminate function analysis was used in order to calculate the linear combinations of the original morphometric and meristic variables which maximally discriminated among the six known groups (Atchley and Bryant 1975). This analysis computed weights for each character and combined the weighted characters into a single score to best discriminate among groups. Graphical displays of these discriminant functions are useful for demonstrating both differences and similarities among groups.

Codominant RFLP genotypes were recorded for each individual and analyzed with the 'Genes in Populations' analysis program (designed by B. May and C. C. Krueger; written by W. Eng and E. Paul, UC Davis). Roger's genetic distances (Roger 1972) were calculated between all population pairs and a phenogram generated using the unweighted pair-group method using arithmetic mean (UPGMA). Significance was tested for all population pairs using likelihood ratio (G^2) tests for homogeneity of gene frequencies across populations.

Table 1. Classification results of meristic data for six populations of spotted sand bass (*Paralabrax maculatofasciatus*). Rows are observed classifications and columns are predicted classifications.

	Percent correct	San Diego	Guerrero Negro	Magdalena Bay	La Paz	Bahia de Los Angeles	Los Pulpos
San Diego	57	17	1	8	0	3	1
Guerrero Negro	30	3	9	10	0	6	2
Magdalena Bay	43	9	1	13	0	6	1
La Paz	17	6	4	6	0	9	5
Bahia de Los Angeles	67	0	4	4	0	20	2
Los Pulpos	0	8	3	11	0	7	1
Total	36	43	22	52	0	51	12

Results

Morphological analysis.—No variation occurred in four of the seven meristic counts (dorsal fin spines, anal fin spines, anal soft rays, and branchiostegal rays). Of the three discriminant function (DF) roots computed for the three remaining characters, only the first was statistically significant ($F = 3.5$, Wilk's *lambda* = 0.75, $p < 0.001$). The correct classification results ranged from 0.00 to 66.6% with an overall rate of 35.6% (Table 1). No populations were grouped with La Paz, which also failed to group with itself. The plot of DF I (Fig. 2) with 95% confidence ellipses shows complete overlap among all sites with no discernible patterns.

The morphometric discriminant function analysis computed five functions to account for 100% of the variation. DF I, II and III described a total of 85.1% of the variation (Table 2) and were highly significant (Table 3). The correct classi-

Fig. 2. Meristic scatterplot showing Discriminant Function I. Ellipsoids indicate 95% confidence limits.

Table 2. Loadings of 19 log-transformed morphometric characters on three disciminant function roots.

Character	DF I	DF II	DF III
Standard length	−1.977	−1.007	−0.831
Body depth	1.476	−2.142	0.781
Caudal peduncle length	−2.313	0.584	0.173
Predorsal length	0.393	−0.616	−0.807
Dorsal base length	−0.611	−0.043	0.087
Anal base length	−1.118	−0.614	0.099
Dorsal fin height	0.826	0.583	0.645
Anal fin height	−0.125	0.688	0.692
Pectoral fin length	−1.105	−0.300	0.683
Pelvic fin length	0.094	0.633	−2.145
Longest dorsal spine	−0.659	−0.414	−1.037
Head length	−0.070	0.017	0.455
Head width	−0.377	−0.894	−1.995
Snout length	1.933	−0.265	−0.088
Suborbital width	0.247	1.218	0.677
Orbit to preopercle	2.711	0.539	1.508
Eye diameter	−0.202	−0.252	0.641
Upper jaw length	0.001	0.847	−0.281
Gape width	0.785	1.595	1.134
Percent Variance			
Individual	50.40%	23.80%	10.80%
Cumulative	50.40%	74.20%	85.10%

fication rates ranged from 73.0 to 100.0% with an overall rate of 86.1% (Table 4). Samples were distinctive along DF I (50.4%) and DF II (23.8%) axes shown with 95% confidence ellipses (Fig. 3). Spotted sand bass from the uppermost Pacific population of San Diego were clearly distinct from the uppermost Gulf, Los Pulpos population. These are the most distant regions of the present range of spotted sand bass. Considerable overlap occurs among the four remaining Baja sites. The Guerrero Negro and Bahia de Los Angeles samples show overlap which follows their geographic positioning as southern adjacents between San Diego and Los Pulpos. The southernmost cape populations, Magdalena Bay and La Paz, overlap with one another and include Bahia de Los Angeles with most of Guerrero Negro. The characters most useful for discriminating between the upper Gulf and upper Pacific regions along the DF I axis are increasing orbit to preopercle and body depths, and shorter caudal peduncle and standard length, respectively. The plot of DF II groups San Diego and Los Pulpos away from Guerrero Negro and

Table 3. Summary of stepwise discriminant analysis of morphometric data. Results for first three calculated roots shown.

Discriminant Function	*F* value	Wilk's *lambda*	p level
I	8.8	0.0267	<0.001
II	6.4	0.1138	<0.001
III	4.9	0.2818	<0.001

Table 4. Classification results of morphometric data for six populations of spotted sand bass (*Paralabrax maculatofasciatus*). Rows are observed classifications and columns are predicted classifications.

	Percent correct	San Diego	Guerrero Negro	Magdalena Bay	La Paz	Bahia de Los Angeles	Los Pulpos
San Diego	100	30	0	0	0	0	0
Guerrero Negro	80	1	24	1	3	1	0
Magdalena Bay	73	1	1	22	6	0	0
La Paz	87	0	2	1	26	1	0
Bahia de Los Angeles	90	0	0	1	2	27	0
Los Pulpos	87	0	0	4	0	0	26
Total	86	32	27	29	37	29	26

Bahia de Los Angeles and reflects their north to south clinal relation to one another. Magdalena Bay and La Paz again overlap and include all sites. The characters most responsible for the variation are increasing gape width and suborbital width describing the southern group while smaller body depth and standard length characterize the northern sites. Results of DF I and DF II combined show that the cape populations are not easily discerned from the remaining sites and are more inclusive. The remaining upper Gulf and upper Pacific sites tend to have tighter clusters which allow for the discernment of geographic patterns. The upper Pacific samples are generally described by smaller fin and body sizes while the upper Gulf groups have larger facial measurements. The plot of DF III (10.8%) shows an overlap of San Diego, Guerrero Negro and Los Pulpos which are the range extremes (Fig. 4). La Paz and Bahia de Los Angeles are separated along the zero axis and Magdalena Bay overlaps the both of them reflecting its clinical

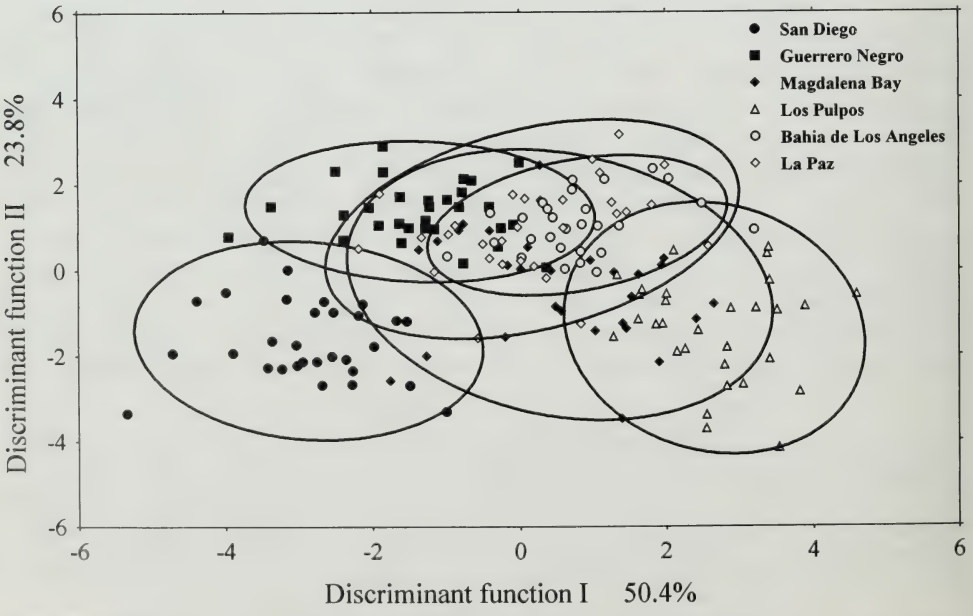

Fig. 3. Morphometric scatterplot showing Discriminant Functions I and II. Ellipsoids indicate 95% confidence limits.

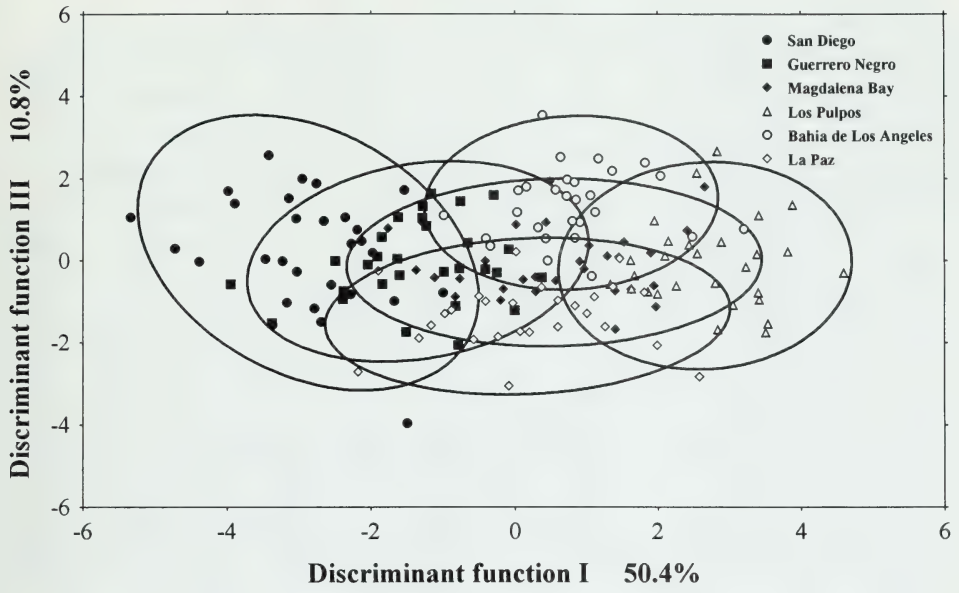

Fig. 4. Morphometric scatterplot showing Discriminant Function III. Ellipsoids indicate 95% confidence limits.

geographic position to these sites. The variation from La Paz to Magdalena Bay and then Bahia de Los Angeles is described by smaller pelvic fin and longest dorsal spine and increasing orbit to preopercle and gape width. Larger facial dimensions with DF III again describe the upper gulf region.

Genetic analysis.—Frequencies of RFLP patterns were calculated for seven of the eleven restriction endonucleases that showed variation (Table 5). A phenogram obtained using Roger's (1972) genetic distance and UPGMA (Sneath and Sokal 1973) clusters the six populations (Fig. 5). G-test results indicate that the gulf populations are genetically similar to one another and are significantly different from the three Pacific populations. The three Pacific populations form two significantly different groups. The northernmost Pacific population of San Diego is significantly different from the two southern-Pacific groups of Guerrero Negro and Magdalena Bay which are the most genetically similar of the six populations.

Discussion

The morphological and genetic results indicate that populations of *P. maculatofasciatus* from the Baja California peninsula form a complex system which cannot simply be divided into disjunct Gulf and Pacific distributions.

The morphometric results indicate that significant differentiation has occurred among populations from the range extremes. Morphometric DF I and DF II describe these as discrete groups according to varying body shapes between these regions. The San Diego and Guerrero Negro populations are distinguished by smaller caudal peduncle, standard length, body depth, and fin characters. This indicates that the upper Pacific spotted sand bass are smaller-bodied and have smaller fins than the upper Gulf group. The Los Pulpos and Bahia de Los Angeles spotted sand bass have larger preopercle, body depth, gape width, and suborbital

Table 5. Arbitrary designation of restriction fragment patterns shown as frequencies.

Enzyme	Population	A	B	C	D	E	F	G	H
BSTU I	San Diego	0	0.7	0.1	0	0	0		
	Guerrero Negro	0.2	0	0	0.5	0	0		
	Magdalena Bay	0.4	0	0	0.5	0	0		
	La Paz	0.1	0	0	0	0.6	0		
	Bahia de LA	0.6	0.2	0	0	0	0.2		
	Los Pulpos	0	0.1	0	0	0	0.5		
DPN II	San Diego	0.4	0.6	0	0	0	0	0	0
	Guerrero Negro	0.6	1	0	0	0	0	0	0
	Magdalena Bay	0	0	0.7	0.1	0	0	0	0
	La Paz	0	0	0.3	0	0.2	0.2	0.3	0
	Bahia de LA	0	0	0	0.7	0	0	0	0
	Los Pulpos	0	0	0	0	0	0	0.6	0.3
HAE III	San Diego	0	0	1	0	0	0	0	
	Guerrero Negro	0	1	0	0.3	0	0	0	
	Magdalena Bay	0.3	0.8	0	0.1	0	0	0	
	La Paz	0.1	0.6	0	0.1	0.6	0	0	
	Bahia de LA	0.5	0.5	0	0	0	0.2	0.2	
	Los Pulpos	0	0	0.4	0.5	0	0.4	0	
HhA I	San Diego	1	0	0	0	0	0	0	0
	Guerrero Negro	0	0.2	0.3	0	0	0	0	0
	Magdalena Bay	0	0	0.5	0	0	0	0	0
	La Paz	0	0	0	0.5	0.1	0.2	0.2	0
	Bahia de LA	0	0	0	0	0.9	0.2	0	0
	Los Pulpos	0	0	0	0	0	0.4	0	0.5
MSP I	San Diego	1	0	0	0	0	0	0	0
	Guerrero Negro	0	0.3	0.5	0	0	0	0	0
	Magdalena Bay	0	0	0.6	0.2	0.1	0	0	0
	La Paz	0	0	0	0	0.3	0.1	0	0
	Bahia de LA	0	0	0	0.3	0	0.2	0.2	0
	Los Pulpos	0	0	0	0	0	0.4	0	0.5
RSA I	San Diego	0	0.9	0.2	0	0	0	0	0
	Guerrero Negro	0.5	0.4	0	0	0	0	0	0
	Magdalena Bay	0.6	0	0.1	0	0	0	0	0
	La Paz	0	0	0	0.2	0.1	0.2	0	0
	Bahia de LA	0	0	0	0	0	0	0.6	0
	Los Pulpos	0	0	0	0	0	0.3	0.6	0.5
Taq αI	San Diego	0.1	0.9	0	0	0	0	0	
	Guerrero Negro	0.8	0	0	0	0	0	0	
	Magdalena Bay	0	0.7	0.1	1	0	0	0	
	La Paz	0	0.3	0.2	0	0.2	0	0	
	Bahia de LA	0	0	0	0	0.1	0.1	0.5	
	Los Pulpos	0	0	0	0	0.8	0.2	0	

width characters. These characters describe a group of larger-headed fish with more robust facial characters. DF III overlaps San Diego, Guerrero Negro, and La Paz but shows some distinction among the cape sites and Bahia de Los Angeles. La Paz and Magdalena Bay are described by smaller pelvic fin and longest dorsal spine fin characters. Bahia de Los Angeles is characterized by larger orbit to preopercle and gape width measurements, again demonstrating the large head dimensions of the upper Gulf group. Magdalena Bay and La Paz samples are very similar morphologically. These share more similarity with the adjacent groups to

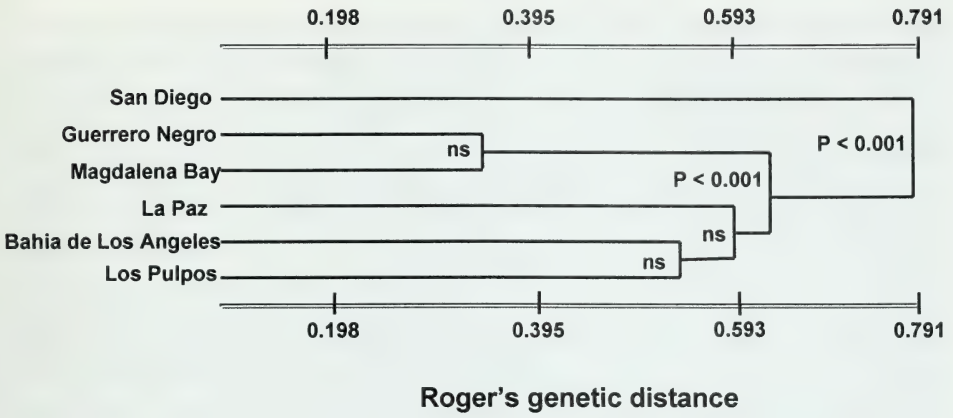

Fig. 5. Phenogram obtained using Roger's genetic distance and UPGMA. Non-significant G-test results are shown as (ns) and P-values for significant tests are shown on the graph. The gulf populations are genetically similar to one another and are significantly different from the three Pacific populations. The three Pacific populations form two significantly different groups. The northernmost Pacific population of San Diego is significantly different from the two southern-Pacific groups of Guerrero Negro and Magdalena Bay that are the most genetically similar of the six populations.

the north, Guerrero Negro and Bahia de Los Angeles, with little overlap with the most distant sites, San Diego and Los Pulpos. These trends describe two broadly inclusive southern populations that are less easily classified. The most distant northern groups become more distinguished from this intermediate, southern region and have the highest classification rates.

Determining the causes of morphological variation among groups has been a difficult task for researchers. The variation of one character or groups of characters may be caused by phenotypic plasticity or by genetic differences among populations. The environment in which a fish develops modifies its shape by accelerating or slowing the rate of development (Hubbs 1926). The northern representatives of a population are usually larger than those to the south. Northern groups grow more slowly and frequently display smaller head and fin proportions than their southern counterparts (Martin 1949). The colder water temperatures of the north alter the timing of transition from one growth stanza to another and produce a new relative growth relationship (Huxley 1932; Martin 1949). Meristic variation is also greatly influenced by the environment. A correlation between cooler environmental temperatures and higher meristic numbers usually result in northern groups having greater meristic counts (Hubbs 1926; Vladykov 1934; Taning 1952). Cooler waters slow growth rates which cause longer developmental periods and allow tissues to develop into a greater number of elements (Gabriel 1944). Southern fishes from warmer waters generally grow faster and display lower meristic numbers. Other influences such as high salinities and low oxygen concentrations parallel the effects of lower temperatures by retarding growth rates (Taning 1952). The genetic determination of morphology has been demonstrated within and between populations (Hubbs 1955). New *Zoarces* individuals transplanted among different environments continued to produce forms that were recognizable from the endemic population (Ege 1942). Individuals from different fish populations reared under comparable conditions continued to produce dissimilar me-

ristic characters (Heuts 1947 1949; Seymour 1956). Determining the source of morphological variation among widely distributed spotted sand bass populations provides similar difficulties. The upper Gulf spotted sand bass are subjected to annual temperature fluctuations of 9–32 °C (Thomson et al. 1987) while San Diego fish experience 14–27°C extremes (Allen 1995b). The salinity in the upper Gulf is stable at 36–37 ppt annually (Brusca 1973) while in San Diego the salinity fluctuates between 32–36 ppt (Allen 1995). These environmental influences may be affecting the development of *P. maculatofasciatus* larvae and juveniles sufficiently to produce significantly different morphologies.

Lindsey (1962) found that fin ray numbers are more strongly influenced by environmental temperature than by parental genotype in *Gasterosteus aculeatus*. If this is the case with *P. maculatofasciatus*, then the physical environment may be a less important influence on morphology than selection due to the complete lack of meristic variation found in this study. Significant morphometric variation could then be the result of natural selection rather than differential development induced by varying physical environments. Spotted sand bass within the southern California bight feed mainly on small fishes, crustaceans, and infaunal bivalves (Allen et al. 1995a). The three Pacific sampling sites and La Paz are soft sediment microhabitats which provide infaunal invertebrate prey. The upper Gulf habitat is dominated by harder, rocky reef substrate upon which spotted sand bass are highly abundant. Ferry and Clark (1997) have demonstrated that the Bahia de Los Angeles spotted sand bass feed on a wider variety of prey and take advantage of the annually fluctuating food resources due to periodic winterkills (Thomson and Lehner 1976). In some cases these fish are dislodging prey items from the reef substrate and are crushing hard-shelled invertebrates. The variable diet of upper Gulf spotted sand bass may require a more robust facial morphology as demonstrated in DF I, II, and III. The higher temperature fluctuation in this region may be selecting for species that acclimate to these environmentally influenced changes in diet. Assuming that morphometric and meristic characters are equally labile, the genetic determination of meristics could weaken the argument for selection versus influence of physical environment on development. Genotype may be controlling meristics regardless of the possible influence of environment on the development of morphometric measures. If counts are more highly conserved than body proportions, then the lack of meristic variability may simply be reinforcing *P. maculatofasciatus* as a single species.

Presumably, genetic differences among geographically widespread species arise from isolation by ecological, physical, and distance barriers. Natural selection, favoring different genotypes, may produce genetic differentiation among isolated regions (Prakash et al. 1969). Differences have been shown to occur among marine organisms with widespread planktonic dispersal capabilities (Present 1987; Waples and Rosenblatt 1987; Grothues 1994). Genetic differentiation has been demonstrated among geographic groups of a larger panmictic population of *Anguilla rostrata* (Williams *et al.* 1973; Koehn and Williams 1978). In these studies, differential selection pressures were sufficient to change gene frequencies on the order of 10% per generation (Williams *et al.* 1973). Genetic differentiation of annual *A. rostrata* cohorts was directed in similar patterns by natural selection (Koehn and Williams 1978).

The population affinities described by RFLP cluster analysis suggest that the

Gulf and Pacific populations are genetically distinct. Although spotted sand bass eggs and larvae stay in the plankton for nearly a month, direct gene flow between Gulf and Pacific regions seems to be limited. The California Current and Gulf surface waters converge to form a persistent oceanic front in the cape region (Roden and Groves 1959; Griffiths 1968). This may restrict the movement of adults as well as drifting eggs and larvae around Cabo San Lucas. The absence of most adults from this region may also be due to a lack of suitable habitat and unfavorably high water temperatures.

In the Gulf of California, prevailing northerly (winter) and southerly (summer) winds cause considerable upwelling and produce year-round plankton blooms (van Andel 1964). Considerable amounts of gene flow are likely with such widespread mixing and strong tidal currents around the larger islands of the upper Gulf. The lack of significant genetic differentiation among the three gulf populations suggests that sufficient mixing may occur throughout this region.

The southerly flowing California Current delivers eggs and larvae from the north along the Pacific coast (Schwartzlose 1964). The clustering of Guerrero Negro and Magdalena Bay in the Pacific indicates that sufficient gene flow is occurring throughout Baja California's southern Pacific region. San Diego is the most genetically distant population in this study, indicating that gene flow between this region and the southern populations is limited. A paucity of serranid larvae between the Southern California Bight and Guerrero Negro may result from a region of upwelling at San Quintin which may limit consistent gene flow between these regions (Moser et al. 1993; Grothues 1994). A study of ten marine shore fishes from southern California and central Baja demonstrated that more rare alleles were delivered from the south and collected in the north (Waples and Rosenblatt 1987). Episodic northward movements of water from the south, including El Nino events, occasionally transport larvae with southern Baja affinities into southern and central California waters (Radovich 1961; Brinton 1981). The results herein indicate that these oceanic phenomena may not be facilitating significant gene flow between the southern Pacific and San Diego populations.

The morphological and genetic evidence demonstrates that significant differentiation has occurred between the Gulf and Pacific regions. Agreement between both lines of evidence lends powerful support to the idea that these areas are restricted from sharing direct gene flow. A clear morphological distinction between San Diego and Los Pulpos is evident with overlap of the southern intermediates, Guerrero Negro and Bahia de Los Angeles. As these groups become more distant, their divergent morphologies may reflect differential selection pressures between different habitats. The molecular evidence indicates that the Pacific and Gulf populations are different, most likely due to a significant reduction of gene flow. Additionally, the significant genetic differences between San Diego and the southern-Pacific populations of Baja indicate that gene flow is also restricted between these regions. The results of this study suggest that geographically isolated populations, under the influence of strong selection pressures, do not require long periods of time for divergence. With a species that matures rapidly, many generations are subjected to selection through evolutionary time. The last 15,000 years may have been sufficient for allowing significant divergence to occur between upper Gulf and Pacific groups of the spotted sand bass.

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Diet and Seed Dispersal Efficiency of the Gray Fox (*Urocyon cinereoargenteus*) in Chaparral

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Abstract.—The frequency of occurrence of prey items in the diet of gray foxes (*Urocyon cinereoargenteus*) in the chaparral of Southern California was determined from scat analysis. Fruit occurred in 70% of scats (n = 106) analyzed and consisted of coffeeberry (*Rhamnus californica*), eastwood manzanita (*Arctostaphylos glandulosa*), toyon (*Heteromeles arbutifolia*), and hollyleaf redberry (*Rhamnus illicifolia*). Mammalian prey included white-footed mice (*Peromyscus* sp., 7%), wood rats (*Neotoma fuscipes*, 4%), and meadow voles (*Microtus californicus*, 1%). Insects, including grasshoppers (Orthoptera, 66%) and Jerusalem crickets (*Stenopelmatus* sp., 54%) composed 14% of prey occurrences. There was only one occurrence of reptilian prey (0.94%), a western fence lizard (*Sceloporus occidentalis*). Seeds passing through the fox's gut were tested to determine germination period. Coffeeberry and redberry ingested by foxes germinated significantly sooner than seeds from fresh fruit ($p = 0.0005$ and 0.03), while toyon germination rates did not differ between fresh and ingested seeds. Days to germination for fresh seeds and seeds from scat averaged 94.6 ± 37.2 and 48.2 ± 25.4 for coffeeberry, 68.9 ± 15.2 and 52.0 ± 8.2 for redberry, and 14.0 ± 2.3 and 22.2 ± 9.0 for toyon.

Seed dispersal occurs in many fruit-eating animals including fish (Horn 1997), primates (Lieberman et al. 1979; Zhang 1995), bears (Applegate et al. 1979; Rogers and Applegate 1983), and most notably birds (Krefting and Roe 1949). Studies of frugivory and seed dispersal have focused on tropical species, and have not investigated temperate fruit and frugivores (Willson 1992). Frugivores act as seed dispersal agents by consuming fruit and defecating or regurgitating the seeds some distance from the parent plant (Traveset and Willson 1997). In addition to transporting seeds, frugivores may have an affect on seed morphology and/or physiology (Schupp 1993). The effects of frugivores on seeds includes releasing the seed from chemicals that inhibit germination (Barnea et al. 1991), scarification of the seed coat (Schopmeyer 1974), and deposition at suitable germination sites (Bustamonte and Canals 1995). In addition, the fruit may have some effect on the frugivore, including increased digestive rates from laxative chemicals in the fruit pulp (Murray et al. 1994; Putz 1993).

Willson (1992) reports that nine families of mammals in North America consume fruit and are potential seed-dispersers. Of these mammals, carnivores are considered the best potential seed dispersal agents due to their large home ranges (Willson 1992). One such carnivore that consumes fruit throughout its range is the gray fox (*Urocyon cinereoargenteus*). The gray fox has morphological specializations for frugivory, including shortened jaws that increase bite speed and

higher digestive efficiency for fruit compared to the more carnivorous red fox (*Vulpes vulpes*; Jaslow 1987). Both the red and gray fox are found throughout the United States, and these specializations would allow the gray fox to partition available food resources, thereby reducing competition with the red fox.

The gray fox has a wide distribution, extending from the Canada and United States border to northern South America (Fritzell and Haroldson 1982). Although gray foxes consume fruit throughout their range, they are more carnivorous in the eastern and southern United States than in the west (Bennett and English 1942; Chaddock 1939; Grinnell and Storer 1924; Hatfield 1939; Korschegen 1957; Nelson 1933; Wood 1954; and Wood et al. 1958). In the Sierra Madre Mountains of Mexico, the diet of gray foxes may be as much as 96% fruit (Delibes et al. 1989). The difference in the amount of fruit consumed by gray foxes may be the result of a difference in climatic conditions between east and west. It has been hypothesized that foxes living in xeric environments may use berries as a reliable source of water (Ball and Golightly 1992).

This study was designed to explore the relationship between gray foxes and the food plants occurring in the chaparral community. If the water use hypothesis is correct, foxes living in chaparral should show an increase in frugivory. In addition, if seeds ingested by foxes are viable after passage through the gut, the fox is a potential seed disperer. We quantified the use of fruit by gray foxes in chaparral habitats, and determined whether seeds were viable after passing through the fox digestive system.

Materials and Methods

Study site.—This study was conducted in the Cleveland National Forest in Orange County, California, at an elevation of 1460 m. The plant community is chaparral (Munz and Keck 1965) dominated by chamise (*Adenostoma fasciculatum*), *Ceanothus cuneata, C. facicuatum, C. spinosa*, manzanita (*Arctostaphylos glandulosa* and *A. glauca*), scrub oak (*Quercus berberidifolia*), and buckthorn (*Rhamnus* spp). The climate is Mediterranean, with hot, dry summers and cold, wet winters. Water sources located in the study site included a perennial spring and two man-made quail guzzlers.

Diet analysis.—A 0.5-km section of road was cleared of scat at the beginning of the study and then scat was collected approximately biweekly. The wet weight of each scat was taken, scats were washed for 3–5 minutes in a 0.5-mm metal strainer placed over a 500-ml beaker to catch small bone fragments that might pass through the strainer. Particles remaining in the sieve were saved for identification. Bone fragments, seeds, carapaces, feathers, skin, hair, and unknown particles were collected.

Identification of prey remains was made using dichotomous keys and reference collections. Incisors and cuticular scale patterns on hair were used to identify rodents. Incisors were identified using Weintraub and Shockley (1980). Hair samples were photographed using a scanning electron microscope at 1000× and cuticular scale patterns were referenced with photographs taken of hair from museum specimens. Seeds were identified using museum specimens and by referencing Martin and Barkley (1961). Total and seasonal diet was analyzed independently. A Chi-square test was performed against the hypothesis that prey would be evenly distributed across the seasons.

The water content of fruit found in the diet was measured using the mean amount of weight lost after the fruit was dried for one week in an oven at 35°C. Fifty individual fruits were used to obtain the mean water content for each species.

Germination Study.—Coffeeberry (*Rhamnus californica*), manzanita (*Arctostaphylos glandulosa*), hollyleaf redberry (*Rhamnus ilicifolia*), and toyon (*Heteromeles arbutifolia*) seeds were collected from scat, and by picking ripe fruit growing in the study site. Fruit pulp was mashed in a bowl of water and seeds were extracted and air-dried. Seeds were then put into a 5% bleach solution for 30 sec to kill fungi. One hundred seeds from fox scats and 100 seeds from fresh fruit were planted in compartmentalized plastic growing trays containing a soil mixture (Applegate et al. 1979; Krefting and Roe 1949; Rogers and Applegate 1983). Germination trays were left on benches outside the California State University, Fullerton greenhouse and were watered daily. Trays were checked daily to determine if seed had germinated, and the date of germination was recorded. Trays were checked until no germination occurred for three weeks.

Coffeeberry, hollyleaf redberry, and toyon did not require any pretreatment, such as cold stratification or scarifiction, prior to planting (Schopmeyer 1974). The mean time to germination for fresh and ingested seeds was compared using a two-tailed t-test. The hypothesis tested was that no difference would exist between the two seed samples. In addition, the number of seeds that germinated between each sample was compared using a pooled probability comparison with a hypothesis of no difference.

Results

Diet.—One hundred and six gray fox scats were collected from the study site. The mean wet weight of scats was 5.15g (± 2.28) with a range of 0.94g to 10.29g. Fruit constituted the most frequently consumed food item and was found in 94.3% of scats. Insects comprised the second most frequent item (26.4%), followed by mammals (22.6%), reptiles (0.94%), and birds (0.94%). Many fox scats contained only one of the major food items. Scat containing only fruit, mammals, or insects occurred 59.4%, 3.8%, and 0.9% of the time respectively.

Fruit from coffeeberry, toyon, eastwood manzanita, and hollyleaf redberry were consumed by foxes. Excepting manzanita, all plants possessed fleshy fruits high in water content. Manzanita fruit was dry and grainy with only 10.1% water. Coffeeberry had the highest water content at 68.8%, hollyleaf redberry had 56.2%, and toyon contained 55.1%. In addition, clumps of undigested grass were found in scats on five separate occasions. Incidental plant material found in scat included the fruit tips and leaf blades of lemonadeberry (*Rhus integrifolia*) and occasional whole dried leaves from assorted plants.

Gray foxes in the study area consumed fruit throughout the year, and specific fruits used reflected the fruiting patterns of the plants (Figure 1). Fruiting times of species consumed were staggered. Manzanita, hollyleaf redberry, and coffeeberry fruited from summer through early winter while toyon fruited during winter and spring. Manzanita had the longest fruiting period and consequently was consumed more than other plants (68% of scat containing fruit had manzanita). Coffeeberry (37%), toyon (14%), and hollyleaf redberry (11%) follow in frequency.

Foxes consumed more insects in spring, perhaps reflecting the decreased availability of fruit. Insect remains primarily consisted of Jerusalem crickets (54% of

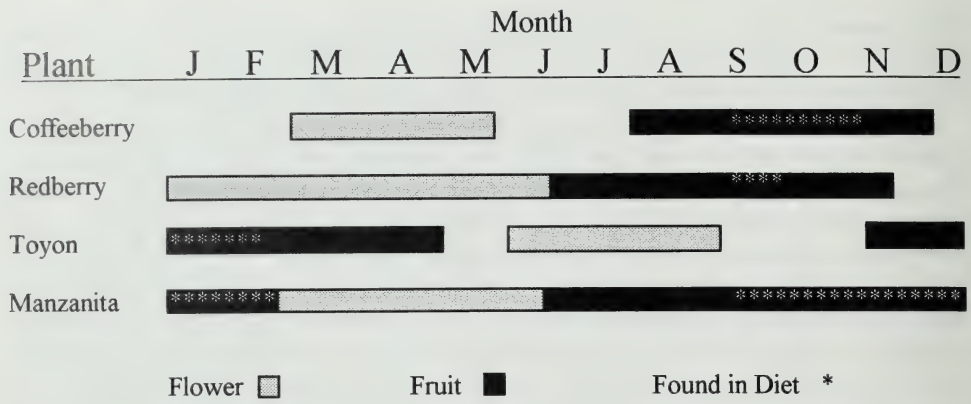

Fig. 1. Flowering and fruiting times of the four plants consumed by chaparral gray foxes. Flowering and fruiting times were determined using observations in the study site over the course of the 1995/1996 season.

insect occurrences), but leg fragments from other orthopterans also were common. A spider, a fragment of a beetle carapace, a bee head, and a small caterpillar were also recorded. Mammal prey included white-footed mice (*Peromyscus* spp., 63%), wood rats (*Neotoma*, 29%), and meadow voles (*Microtus*, 8%). One scat contained a western fence lizard (*Sceloporus occidentalis*), and another scat contained an unidentified bird.

The diet of the gray fox changed seasonally (Figure 2). Fall (September–November) and winter (December–February) diets contained mostly fruit, which occurred in 97.8% and 100% of the scat respectively. Insects (24.4% fall, 16.0% winter) were the second most important prey types followed by mammals (15.6% fall, 12.0% winter). Spring (March–May) diet was significantly different (X^2 analysis, $p < 0.001$) from fall and winter. The use of fruit in spring (50% occurrence) was about half of that used in fall and winter. In addition, the occurrence of insects (44% occurrence) in scats during spring was more than double that of other seasons. Mammal use declined during the spring months to 4.0%.

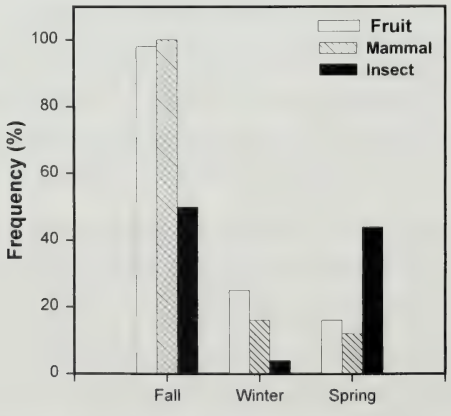

Fig. 2. Seasonal difference in the diet of the chaparral gray fox. Summer data were not available due to an outbreak of canine distemper and the subsequent death of all foxes in the study population. Foxes had not returned to the study site as of April 1997.

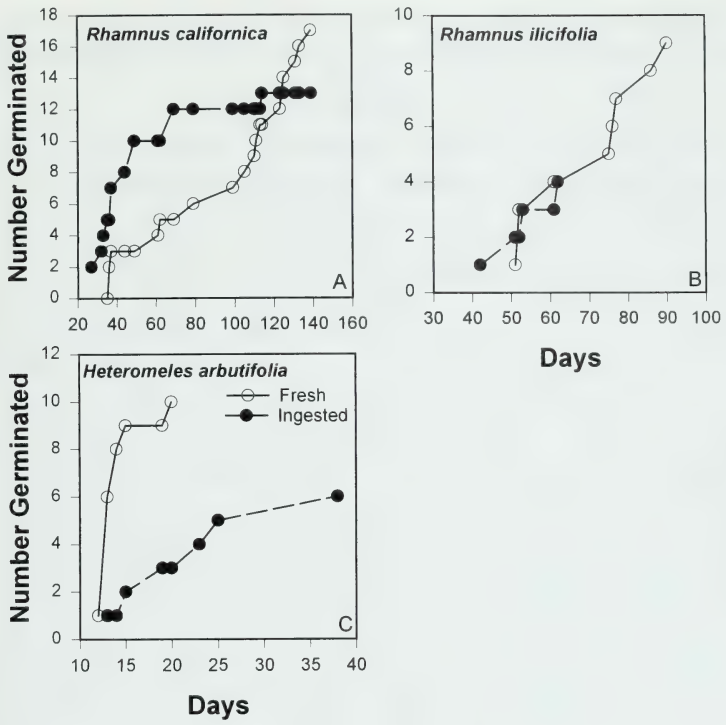

Fig. 3. Germination rate for seeds from (a) coffeeberry (*Rhamnus californica*), (b) hollyleaf Redberry (*Rhamnus illicifolia*), and (c) toyon (*Heteromeles arbutifolia*). For each species, 100 seeds were collected from fresh fruit in the study site and 100 seeds were collected from fox scat. Fresh samples of redberry seeds were obtained from the seed bank at Rancho Santa Ana Botanic Gardens, Claremont, CA.

Germination.—Seeds that passed through the fox's digestive system showed different rates of germination (Figure 3). Coffeeberry seeds from scats germinated significantly earlier (Two tailed T-test, $p = 0.0005$) compared to seeds from fresh fruit (Figure 3a). The mean number of days to germination was 94.6 ± 37.2 and 48.2 ± 25.4 for the freshly picked and ingested seeds respectively. Ingested seeds began growing eight days earlier than the freshly picked seed and followed similar germination rate thereafter. Seventeen seeds germinated in the freshly picked sample and 13 germinated from the ingested sample; however, this difference was not statistically significant (Pooled probability comparison, $p = 0.22$).

Hollyleaf redberry also exhibited a significantly earlier germination time (Figure 3b) for seeds from scats compared to fresh seeds (Two tailed T-test, $p = 0.03$). The mean days to germination for the fresh and scat samples was 68.9 ± 15.2 and 52.0 ± 8.2 respectively. Nine fresh and 4 scat seeds germinated; however, the difference was not significant (Pooled probability comparison, $p = 0.08$).

The mean germination time for fresh and ingested toyon seeds was 14.0 ± 2.3 and 22.2 ± 9.0 days (Figure 3c). The depressed germination rate for the scat sample was not significant (Two tailed T-test, $p = 0.08$). Fresh seeds began germinating one day before the fox sample. The number of seeds that germinated in

the two samples was 10 fresh and 6 ingested. The difference in the number of seeds that germinated is not significant (Pooled probability comparison, $p = 0.14$).

Discussion

Diet.—A mostly frugivorous diet was observed in foxes from this study. Similar observations were made in oak-pine woodlands in the Sierra Madre of Mexico where 96% of the scat contained manzanita (Delibes et al. 1989). Grinnell and Storer (1924) state that scat of gray fox found in early winter and fall often contained manzanita seeds and hulls.

Ball and Golightly (1992) suggest that gray foxes may consume fruit more for water than as a source of energy. In the hot, dry environment of the chaparral water could be a limiting factor; however, on our study site there are several sources of water. Laurel Spring, located within the fox's home range, runs as a trickle during summer months, but flows steadily following winter rain. This spring supplies enough water to drink year round and collects in pools at the bottom of the canyon.

Fruit from coffeeberry, toyon, and redberry are all high in water content (68.8, 56.1, and 55.6% respectively), but were not the most frequently consumed fruit. Manzanita, with the lowest water content (10.1%), was most frequently consumed (64.25%) followed by redberry (14.5%), toyon (12.8%), and coffeeberry (10.3%). If water was the main factor in fruit consumption, foxes should choose to eat succulent fruit more frequently. But foxes consumed more dry fruit, leading to the conclusion that, although fruit may supply water, it is primarily consumed for energy. There are other plants in the fox home range that have fruit with high water content, such as white flowered currant (*Ribies indecorum*), that are not consumed. Over half of the scat collected contained only fruit remains, suggesting that fruit can supply a substantial amount of the fox's energy requirements.

The high use of fruit by gray foxes in chaparral may be an adaptation to reduce competition between the foxes and other carnivores that inhabit the same area. Pequegnat (1951) lists the gray fox as the most abundant carnivore in the chaparral community. A frugivorous diet, in conjunction with tree climbing ability, would allow the gray fox to exploit resources not available to other carnivores.

Germination.—Seeds from three of the four plant species tested were viable after gastrointestinal passage, indicating that the fox may be a seed dispersal agent for these species. Seeds from coffeeberry and hollyleaf redberry exhibited more rapid germination after passing through the fox. Earlier germination would allow the seedlings to become established after the first rain of the season. In addition, quicker germination results in less exposure to predation by insects and infection by fungi. Although germination of toyon seeds was not enhanced by the fox's digestive system, they still might benefit from the increased dispersal provided by foxes.

Scat was deposited in the road, usually on low flat rocks. Grinnell and Storer (1924) also note that gray foxes seem to deposit scat on open roads and the tops of rocks. These locations appear to be a poor location for seedling development; however, rain might break up and dissolve scat and wash seeds off the rock and onto the soil (Leiberman et al. 1979).

A presumed benefit of animal dispersal is the opportunity for seeds to be deposited in locations not accessible through other means of dispersal. Without a

mobile disperser, fruit might simply fall off the plant, and seedlings would become established directly under or downslope from the parent plant. An animal disperser provides seeds with the possibility of moving upslope and great distances from the parent plant. A similar effect has been documented in the Machaca (*Brycon guatemalensis*), a fig eating fish from Costa Rica (Horn 1997). The Machaca feeds on figs that fall into the water and swim upstream depositing the seeds along the river's bank.

The gray fox may provide a means of dispersal for plants in the chaparral in return for the nutrition fruit provides. This interaction may be important in regeneration of the chaparral ecosystem. Orange County, California is currently undergoing extensive development. Foxes may be displaced leaving plants without an important dispersal agent.

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Records of the Oarfish *Regalecus glesne* Ascanius, 1772 in the Eastern Pacific Ocean

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The monotypic teleost genus *Regalecus* has a worldwide distribution, mainly in tropical and temperate seas. Although other species have been named in this genus (e.g. Mori 1956; Nishimura 1960; Scott et al. 1980; Lindberg et al. 1980; Fujii 1984; Chavez et al. 1985), it seems likely that *Regalecus glesne* is the only valid species (Smith and Heemstra 1986; Nelson 1994). The other monotypic regalecid genus, *Agrostichthys* is represented by *Agrostichthys. parkeri* in the southeast Atlantic, and off New Zealand and Tasmania. *Regalecus glesne* has been recorded from the Atlantic Ocean and Mediterranean Sea (Palmer 1973), the Indian Ocean, and the eastern Pacific (Fitch 1951; Fitch and Lavenberg 1968; Miller and Lea 1972; Hubbs et al. 1979; Eschmeyer et al. 1983). It is believed to inhabit the mesopelagic zone but occasionally is found in the upper level of the epipelagic zone. It is a rare species and almost all records are based on dying or dead, often beached, individuals (Fitch and Lavenberg 1968; Smith and Heemstra 1986).

We report unpublished records of 31 *Regalecus glesne* collected in the Eastern Pacific from 1961 to 1997 (Fig. 1). The fishes were collected by net (one juvenile),

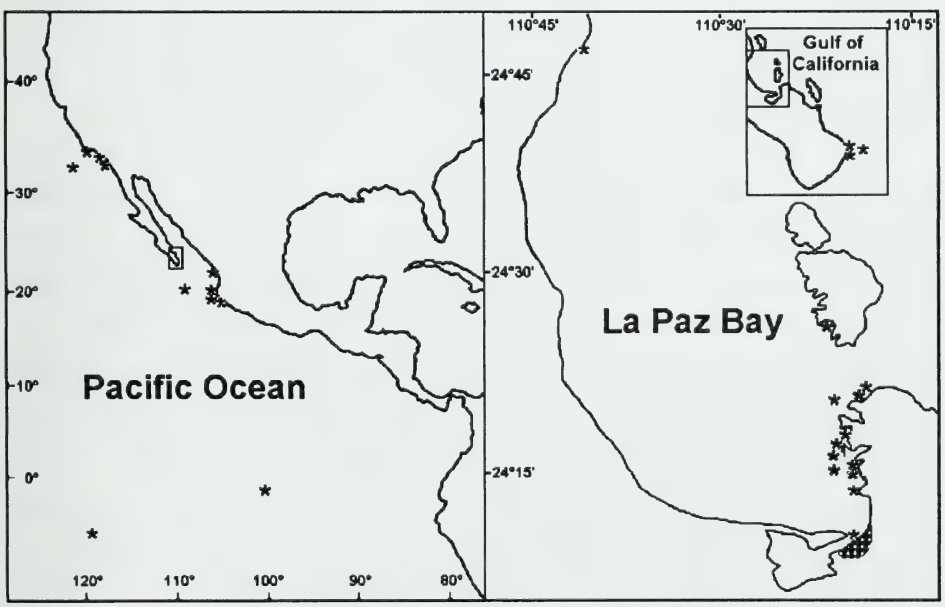

Fig. 1. Records of *Regalecus glesne* in the Eastern Pacific Ocean.

Table 1. Records of *Regalecus glesne* in the Eastern Pacific Ocean. SIO = Scripps Institution of Oceanography; CICIMAR = Centro Interdisciplinario de Ciencias Marinas; UABCS = Universidad Autónoma de Baja California Sur.

Locality	Latitude	Longitude	Date	Size mm	Reference
80 mi SW of San Diego	32°45′N	117°13′W	07 Aug 1961	3540	SIO 61-389
Eastern Pacific	06°38′S	118°59′W	29 Feb 1968	62	SIO 96-31
Eastern Pacific	02°16′S	100°34.7′W	26 Nov 1969	590	SIO 69-496
Bahía de La Paz	24°20′N	110°20′W	1979	?	CICIMAR file
Bahía de La Paz	24°15′N	110°20′W	1982	?	CICIMAR file
Pichilingue, B.C.S.	24°17′N	110°19′W	01 Jul 1984	1970	UABCS(0752)
Playa Tecolote, B.C.S.	24°21′N	110°18′W	01 May 1985	3000	CICIMAR file
Pichilingue, B.C.S.	24°17′N	110°19′W	06 May 1985	3000	CICIMAR file
Playa Tecolote, B.C.S.	24°21′N	110°18′W	16 Jun 1985	3930	CICIMAR file
S. of San Juan Seamount	32°30′N	121°00′W	42 Jan 1986	4330	SIO 86-1
Bahía de La Paz	24°16′N	110°19′W	1987	?	CICIMAR file
Ensenada de La Paz	24°12′N	110°18′W	28 May 1988	4700	CICIMAR file
Playa del Tesoro, B.C.S.	24°16′N	110°19′W	28 May 1988	?	CICIMAR file
Punta Colorada, B.C.S.	24°13′N	110°18′W	01 Jun 1988	4900	UABCS file
El Quelele, B.C.S.	24°12′N	110°30′W	02 May 1989	4500	CICIMAR file
Bahía de Tenacatita, Jalisco	19°10′N	104°50′W	01 Apr 1991	4000	CICIMAR file
Isla Espíritu Santo, B.C.S.	24°24′N	110°20′W	16 July 1991	5650	CICIMAR file
Punta Prieta, B.C.S.	24°16′N	110°19′W	17 July 1991	4000	CICIMAR file
El Mechudo, B.C.S.	24°48′N	110°40′W	16 Mar 1993	4780	CICIMAR file
Yelapa, Pto. Vallarta, Jalisco	20°30′N	105°25′W	Sept 1993	2000	CICIMAR file
Compostela, Nayarit	21°10′N	105°20′W	May 1994	2800	CICIMAR file
Bahía de La Paz	24°12′N	110°30′W	Aug 1994	5500	CICIMAR file
Los Barriles, B.C.S.	23°40′N	109°41′W	12 July 1995	3720	CICIMAR file
Los Barriles, B.C.S.	23°40′N	109°41′W	12 July 1995	5090	CICIMAR file
Sea of Cortez	23°40′N	109°30′W	18 Sept 1995	5000	CICIMAR file
Isla Espíritu Santo, B.C.S.	24°24′N	110°20′W	08 Dec 1995	3000	CICIMAR file
Puerto Vallarta, Jalisco	20°30′N	105°25′W	25 Jan 1996	4050	CICIMAR file
Puerto Vallarta, Jalisco	20°30′N	109°25′W	25 Jan 1996	4080	CICIMAR file
Isla Espíritu Santo, B.C.S.	24°24′N	110°20′W	16 July 1996	5300	UABCS file
Coronado:US Naval Special Warfare	32°40′N	117°14′W	19 Sept 1996	7300	SIO 96-82
Ca 17 miles W of Point Loma	32°41′N	117°15′W	26 Oct 1997	5000	SIO 97-226

or beached or weakly swimming from waters close to California to oceanic waters just south of the equator (Table 1).

Interestingly the species becomes stranded during the same seasons, the season that these organisms appear in winter through early summer, in the eastern Pacific, in Japanese waters (Nishimura 1962), and on the western coast of Florida (Saloman et al. 1973). Nishimura (1962) analyzed the temperature-salinity relationship of the water mass from which oarfish were supposedly taken and suggested that this species inhabits depths between 100–200 m to 400–700 m in the western North Pacific and from 25–50 m to 150–200 m in the Japan Sea. The Gulf of California has deep water close to the tip of the Baja California peninsula, with 3,000 m depths fairly near the coast (Thomson et al. 1979). There are deep channels, 400–700 m, close to Bahia de La Paz and to Cerralvo Island, Espiritu Santo Island, and Los Barriles. Similarly, there are deep waters close to the California and equatorial localities where these fishes were collected.

Of the 15 oarfish found in Florida between 1920 and 1967 (Taylor and Saloman

1968), only one was caught with a net (to 450 m depth) and most were in poor condition. There have been many hypotheses proposed (e.g., parasites, red tide, predation, abrupt temperature changes, storms, and migration for reproduction) for the moribund condition of this species (Goode and Bean 1895; Walters 1959; Hutton 1961; Serventy 1966; Hulley and Rau 1969; Parin 1970), but no substantial conclusions.

We propose to do more detailed taxonomic and genetic studies in the future to learn more about this rare species. In the southern Gulf of California, the average occurrence is one or two per year, which affords more opportunities to study this species.

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First Records of Two Tropical Gobies, *Awaous tajasica* and *Ctenogobius sagittula* (Pisces: Gobiidae), in the Continental Waters of Baja California, México

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On 23 August and 10 October 1998, two species of gobies (*Awaous tajasica* and *Ctenogobius sagittula*), both of Tropical affinity (Follett 1960; Castro-Aguirre 1978), were collected in the lower Río [Arroyo] San Fernando, between Punta San Antonio and Punta San Fernando, Baja California (B.C.), México (29° 43′ 33.7″ N, 115° 38′ 49.6″ W, Fig. 1). These are the first records of these species in the continental waters of the state of Baja California; a new northern distributional record for *A. tajasica*, and the first mainland record in the peninsula of Baja California for *C. sagittula*. Specimens are deposited in the fish collection of the Facultad de Ciencias, Universidad Autónoma de Baja California (UABC), at Ensenada.

The Río San Fernando (INEGI 1995) is in the northernmost drainage of the Vizcaino faunal district (Nelson 1921). This, and many other sites of this district have not been previously sampled for fishes, as reflected by the absence of continental fish records from south of Río El Rosario to Río Santo Dominguito (Follett 1960; Castro-Aguirre 1978; Ruiz-Campos and Contreras-Balderas 1987).

The lower Río San Fernando was sampled with minnow traps, minnow seine and experimental gill net from its mouth to 1 km upstream. Its mouth is blocked by a wide bar of sand and boulders at the high tide level, which impounds a slough approximately 200 m long and 60 m wide. The salinity of the water was measured with an Hydrolab Scout 2 equipment (Hydrolab Co., Austin, Texas) at different points along the slough. The slough is vegetated by dense macrophytes (*Chara* sp.) and bordered by saltmarsh vegetation (e.g., *Salicornia bigelovii, Distichlis spicata*, and *Juncus acutus*).

Awaous tajasica (Lichtenstein 1822)

Previous range.—This amphiamerican species (Castro-Aguirre et al. 1999) is distributed in the Pacific drainage from the Gulf of California (lower Río Yaqui at Sonora, México; Hendrickson et al. 1980) to Perú (Miller 1966; Castro-Aguirre 1978). In the peninsula of Baja California, this goby has been previously recorded at: town of La Purísima [at stream of the same name] (Evermann 1908); "Boca

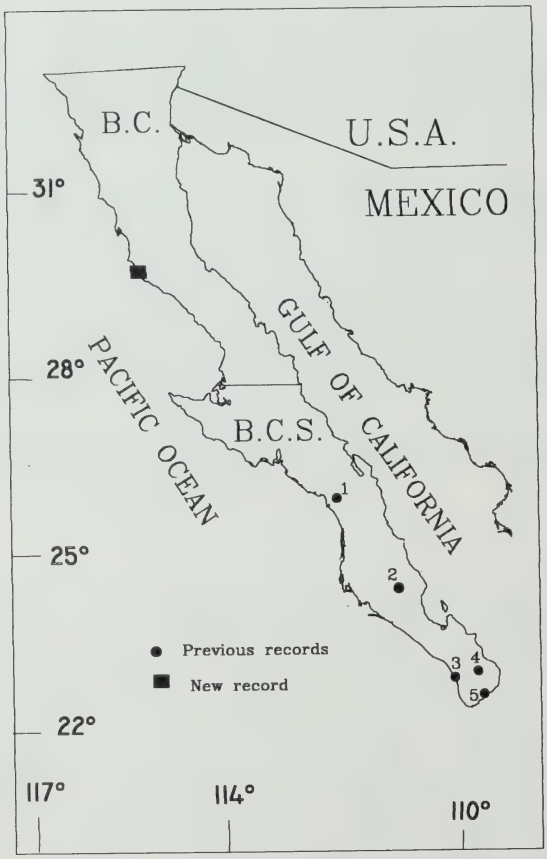

Fig. 1. Previous and new records of *Awaous tajasica* (Pisces: Gobiidae) in the peninsula of Baja California, México. (1) Arroyo La Purísima at town of La Purísima, (2) Arroyo Las Pocitas at Pozas del Vado, (3) lower Arroyo Grande ca. Todos Santos, (4) Boca de la Sierra at Santiago, and (5) lower Río San José del Cabo at San José del Cabo.

de la Sierra at Santiago" [stream of] (De Buen 1942); Río San José del Cabo [lower part] (Follett 1960; Castro-Aguirre, 1978); Arroyo Las Pocitas [at "Pozas del Vado"] (Espinosa Pérez and Castro-Aguirre 1996); and recently, in the lower part of Arroyo Grande ca. Todos Santos (UABC-771, G. Ruiz-Campos, unpublished data) (Fig. 1).

Material examined.—Thirty six specimens from three sites in the lower Río San Fernando, B.C.: **UABC-832** (n = 7, 69.0–79.7 mm standard length [SL]), ca. 200 m above mouth (salinity 4.1 ppt), 23 August 1998; **UABC-836** (n = 3, 84.0–98.0 mm SL), ca. 50 m above mouth (salinity 4.3 ppt), 10 October 1998; and **UABC-838** (n = 26, 32.3–96.0 mm SL), ca. 1 km upstream (salinity 3.9 ppt), 10 October 1998.

Description.—This goby (Fig. 2-A) has the following identifying characters (cf. Jordan and Evermann 1896–1900; Castro-Aguirre 1978): body compressed posteriorly, rather depressed anteriorly; head broader than deep; eyes small, less than interorbital width; mouth large, horizontal, maxillary extending to below anterior part of orbit in adult male, shorter in young; inner edge of the shoulder

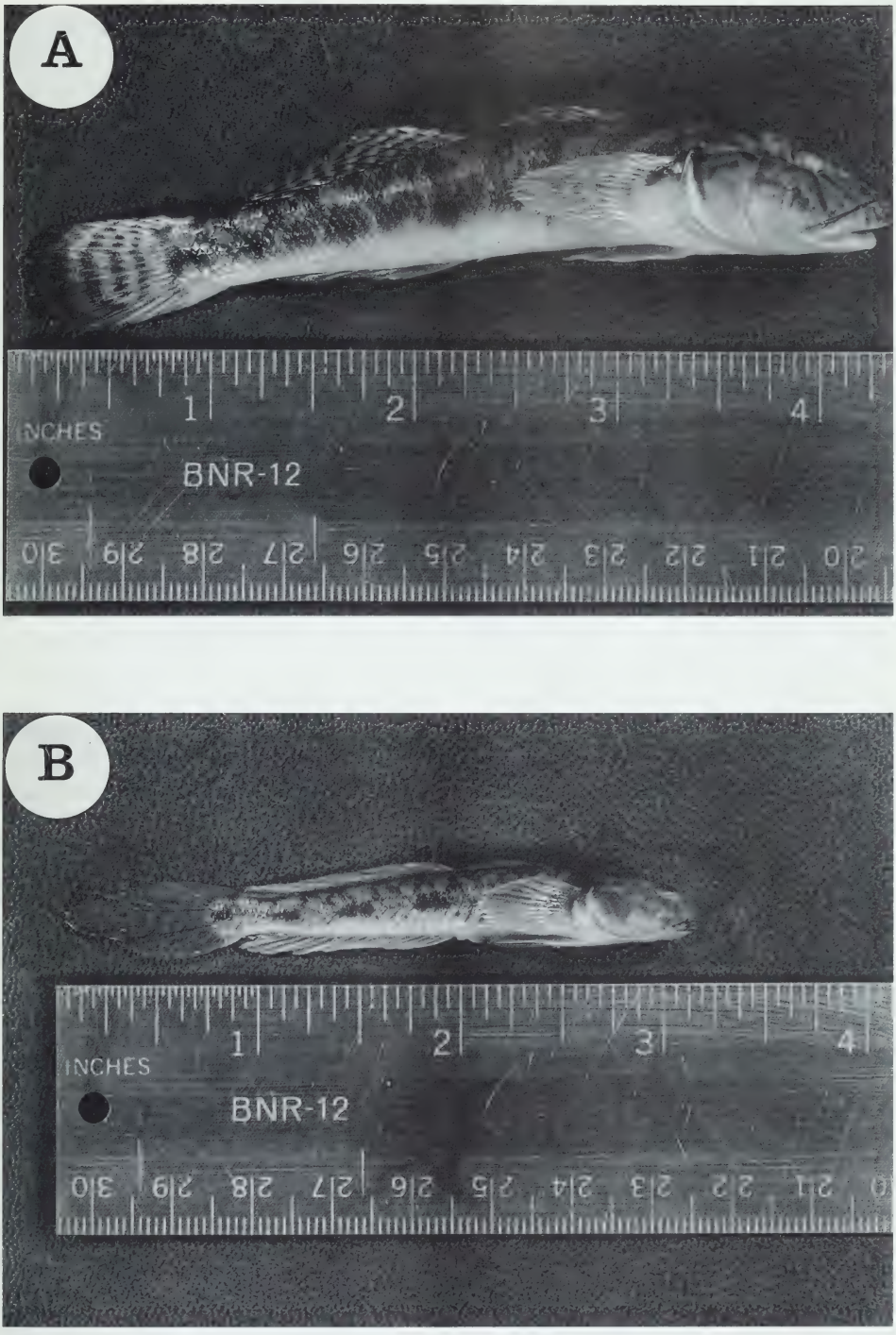

Fig. 2. (A) *Awaous tajasica* (Lichtenstein, 1822) (UABC-838) and (B) *Ctenogobius sagittula* (Günther, 1861) (UABC-837).

girdle with 2 or 3 rather large papillae; dorsal I-11, anal 11; 59 to 68 scales in lateral series; head length 6.0 times eye diameter; body olivaceous with a series of roundish blotches along the middle of side; dark narrow streaks radiating from eye; and a blackish streak crossing the upper edge of the opercle.

Comments.—Two species of *Awaous* are currently recognized for Tropical America (cf. Castro-Aguirre et al. 1999): *Awaous tajasica* (Lichtenstein 1822) of amphiamerican distribution, with its junior synonym *A. transandeanus* (Günther 1861) [previously assumed to be exclusively from the Pacific drainage] and *Awaous banana* (Cuvier and Valenciennes 1837), which is confined to the Guyanas and Brazil. Comparative biochemical or molecular study of populations of "*A. tajasica*" from Pacific and Atlantic drainages might clarify relationships and taxonomy. Río San Fernando is approximately 533 km north of the nearest previously known locality in the peninsula of Baja California (Follett 1960). The finding of this ubiquitous goby (Castro-Aguirre 1978) as far north as Río San Fernando is likely correlated to the presence of a surface warm water mass related to the "El Niño" oceanographic event.

Ctenogobius sagittula (Günther 1861)

Previous range.—From Gulf of California and adjacent waters south to Panama (Jordan and Evermann 1896–1900), with disjunctive coastal records in San Ignacio lagoon, B.C.S. (De La Cruz-Agüero and Cota-Gómez 1998), San Quintín Bay, B.C. (Rosales-Casián 1996), and San Diego Bay, California (Miller and Lea 1972). Previous mainland México records of longtail goby (*C. sagittula*) are Laguna Caimanero and Escuinapa (Sinaloa), Mar Muerto (Chiapas), and Lagunas Oriental and Occidental at Oaxaca (Castro-Aguirre 1978). It had not been previously reported in continental waters of the peninsula of Baja California (cf. Follett 1960; Castro-Aguirre 1978).

Material examined.—Two specimens from the lower Río San Fernando, B.C.: **UABC-837** (53.2–60.4 mm SL), ca. 200 m above mouth (salinity 3.9 ppt), 10 October 1998.

Description.—This taxon (Fig. 2-B) is distinguished by the following characteristics (Jordan and Evermann 1896–1900; Miller and Lea 1972): slender body, quite sharpened from middle of first dorsal to caudal, most compressed posteriorly; caudal fin longer than head; body depth 6.1 to 6.3 times in standard length; short head, depressed, and broad; large mouth, nearly horizontal, the maxillary in adults extending beyond middle of eye; teeth in a narrow band in each jaw, those in lower jaw uniform, and the outer series in upper jaw very enlarged and separated by an interspace from the inner band; 65 to 66 scales in a longitudinal series; first and second dorsal fins with 6 soft spines and 13 rays, respectively; anal rays (14); body light yellow-brown with five elongated black blotches on sides.

Comments.—This Panamanian gobiid fish is a senior synonym of *Gobionellus longicauda* Girard 1858 (Robins and Lachner 1966) and *Gobius longicauda* Jenkins and Evermann 1889 (cf. Castro-Aguirre 1978; Castro-Aguirre et al. 1999; and Watson and Horsthemke 1995), which was first reported as far north as San Diego Bay (southern California) in the early 1900's (Starks and Morris 1906), but without subsequent records (Swift et al. 1993). Its current status in California is considered as extirpated (Swift et al. 1993). Recently, this goby was reported

in San Ignacio lagoon (De La Cruz-Agüero and Cota-Gómez 1998) and San Quintín Bay (Rosales-Casián 1996).

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